ADDENDUM

TO THE

HANDBOOK

OF THE

HOSPITAL CORPS

UNITED STATES NAVY

1939

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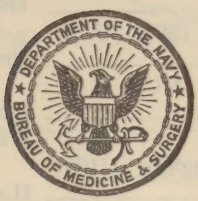

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ADDENDUM

To make available to users of the *Handbook of the Hospital Corps, U. S. Navy, 1939*, new information regarding the treatment and care of the sick and injured, an addendum is included in this reprint of the *Handbook*. The subjects considered therein appear in the same order as in the *Handbook*.

Material from the *BuMed News Letter* has been freely used, including parts of abstracts appearing originally in non-military journals. Reference also has been had to many standard texts relating to the various subjects. Consequently, it is impossible to give credit to all the many workers in various fields who also are, in a sense, contributors.

The Bureau of Medicine and Surgery herewith expresses appreciation to the following officers who have contributed the sections or parts of sections shown after their respective names:

Lieut. Commander D. C. Baker, (MC), U. S. N. R.	Fungus Infections of the External Auditory Canal.
Lieut. Commander E. E. Barksdale, (MC), U. S. N. R.	Fungus Infections of the Feet.
Lieut. Commander R. B. Bigelow, (MC), U. S. N. R.	Cold and Chilling.
Lieut. Commander J. F. Conner, (MC), U. S. N. R.	Penicillin.
Lieut. Commander E. L. Corey, H–V(S), U. S. N. R.	Blast Injury.
Lieut. Commander P. H. Futcher, (MC), U. S. N. R.	Demineralization of Sea Water.
Lieut. Commander J. W. Haviland, (MC), U. S. N. R.	Diarrheal Diseases.
Lieut. Commander E. C. Hoff, (MC), U. S. N. R.	Medical Problems in Aviation.
Lieutenant C. P. Katsampes, (MC), U. S. N. R.	Insect Control.
Lieutenant D. R. Mathieson, (MC), U. S. N. R.	Purification of Temporary Water Supplies.
Lieut. Commander N. L. Saunders, (HC), U. S. N.	History and Chemistry of the Sulfonamides.
Commander W. H. Schwartz, (MC), U. S. N.	Prophylaxis and Treatment of Gonorrhea.
Commander A. J. Vorwald, (MC), U. S. N. R.	Chemical Warfare.
Lieut. Commander A. P. Webster, H–V(S), U. S. N. R.	Night Vision.
Staff of School for Pharmacist's Mates Entering the Submarine Service	Diving and Submarine Duty.
Editors of the *BuMed News Letter*	Other sections or parts of sections.

ROSS T MCINTIRE,
Surgeon General, U. S. Navy.

ANATOMY AND PHYSIOLOGY

Night Vision.—As stated on page 82 of the *Handbook*, the retina possesses two types of visual cells, namely rods and cones. These two types of light receptors serve different visual functions. The cones, so-called because of their conical shape, are concerned with the perception of color and with day vision at high intensities of light. The cones are especially concerned with what is called *central vision*, which will be discussed further. The rods represent one's "night eyes" and are particularly concerned with vision at low intensities of

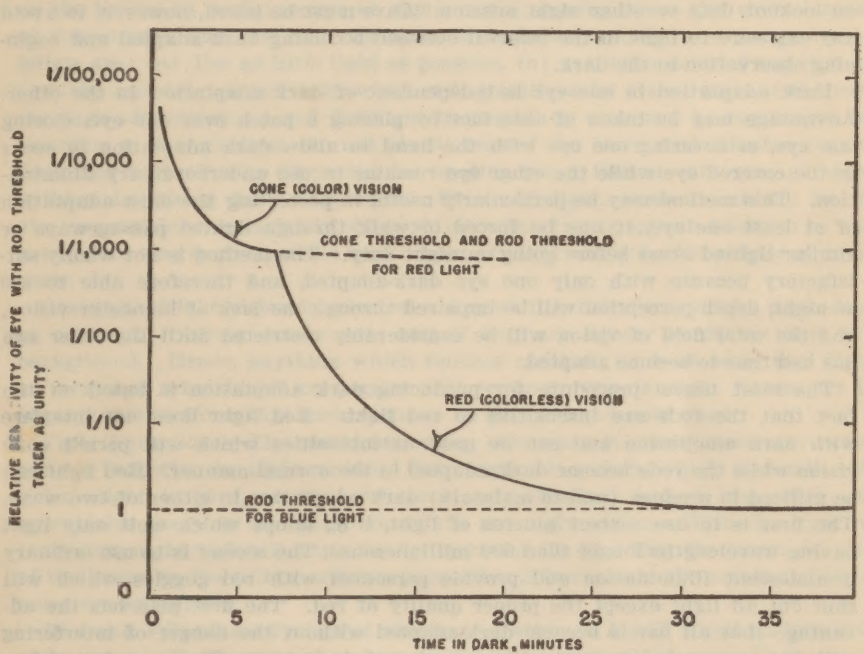

FIGURE 1.—Chart showing the course of dark adaptation. On the vertical axis is shown the relative sensitivity of the eye with the maximum sensitivity at rod threshold taken as 1. Note that dark adaptation proceeds rapidly at first, then more slowly, and is practically complete after half an hour. The first portion of the curve shows the adaptation of the cones. They become more sensitive to light. This process requires about 7 minutes. Complete adaptation of the rods, however, as shown by the second portion of the curve, requires altogether about 30 minutes. It is apparent from the chart that the cones become 100 times as sensitive and the rods 100,000 times as sensitive. As only the cones possess color vision, the source of light just perceptible to the dark-adapted rods would have to be increased in intensity 1,000 times to be perceived by the cones as colored.

illumination. Night vision is sometimes referred to as colorless vision because the rods do not perceive color.

Dark Adaptation.—A transition from cone vision (day vision) to rod vision (night vision) occurs on going into darkness from an illumination bright enough to read by, and it is this transition which is of prime importance to the night lookout or to anyone going on night duty. The course of the adjustment from day vision to night vision is called dark adaptation. In figure 1 is shown the

course of dark adaptation with the relative sensitivity of the eye plotted against time in the dark. Note that during about the first 7 minutes in the dark the intensity of the light which can be seen by the cones is decreasing. At this point the cones have reached their maximum sensitivity, and the further increase in sensitivity of the eye is due to the increase in the sensitivity of the rods. It takes, on the average, 30 minutes for the rods to reach maximum sensitivity. This fact is of prime importance in modern warfare. A lookout coming from a lighted room to stand watch at night will require approximately 30 minutes before night vision will be at highest efficiency. If standing watch while the eyes are undergoing dark adaptation, the lookout may miss detection of the enemy. This gives rise to an important aspect of night vision, namely, methods of producing dark adaptation prior to night duty.

Methods for Producing Dark Adaptation.—One way to achieve dark adaptation is simply to remain in complete darkness for at least half an hour before going on lookout duty or other night mission. Care must be taken, however, to avoid any exposure to light in the interval between becoming dark adapted and beginning observation in the dark.

Dark adaptation in one eye is independent of dark adaptation in the other. Advantage may be taken of this fact by placing a patch over one eye, closing one eye, or covering one eye with the hand to allow dark adaptation to occur in the covered eye while the other eye remains in use under ordinary illumination. This method may be particularly useful in protecting the dark adaptation of at least one eye, if one be forced to walk through lighted passageways or similar lighted areas before going on night duty. The method is not wholly satisfactory because with only one eye dark-adapted, and therefore able to see at night, depth perception will be impaired through the lack of binocular vision, and the total field of vision will be considerably restricted until the other eye has had time to become adapted.

The most useful procedure for producing dark adaptation is based on the fact that the rods are insensitive to red light. Red light does not interfere with dark adaptation and can be used at intensities which will permit cone vision while the rods become dark adapted in the normal manner. Red light can be utilized to produce (and to maintain) dark adaptation in either of two ways. The first is to use correct sources of light, i. e., lamps which emit only light having wavelengths longer than 600 millimicrons. The second is to use ordinary incandescent illumination and provide personnel with red goggles which will shut out all light except the proper quality of red. The first plan has the advantage that all hands become dark-adapted without the danger of interfering with the process by inadvertently removing their goggles. The second plan has the advantage that only those preparing for night-observation duty need wear the red goggles while all others may make use of normal illumination. The value of using red light to produce dark adaptation is that during the half hour necessary to adapt, cone vision is unimpaired and useful work may be accomplished. The obvious disadvantage and discomfort of having to remain in complete darkness for half an hour is overcome. Specifications have been prepared for goggles for dark adaptation and the Navy dark-adaptor red goggles are issued for this purpose.

Light Adaptation.—The first principle in the use of the eyes at night is to allow dark adaptation to occur. The second principle is to *preserve dark adaptation.* Light adaptation, as the name implies, is the reverse of dark adaptation. Exposure of the dark-adapted eye to light will cause an impairment of night vision proportional to the intensity of the light and the time of exposure to the light. In general, 1 to 3 minutes' exposure to light of the ordinary intensities

found in lighted rooms is sufficient completely to destroy dark adaptation and one-half an hour in the dark or under red light will be required to re-obtain maximum night vision. In general, a few seconds' exposure to light in passageways or similarly lighted areas is sufficient to impair dark adaptation to such a degree that as a result 3 to 10 minutes will be required to restore it. Exposure to very high intensities of light for a fraction of a second, such as that from gun flashes or a photographic flash bulb will strongly impair dark adaptation, but only for from a few seconds to a minute or two. The importance of the preservation of dark adaption can scarcely be overemphasized. It is best to avoid light of all sorts, the flare of matches, flashlights, lights in passageways, and even instrument lights if possible. The only safe light is the Navy's official red light.

Instrument Illumination.—Frequently, it will be impossible to act without the use of some light, as for example, in airplane cockpits, in reading instruments on the bridge, in reading maps at night, in the conning tower and control room of submarines, and the like. In these situations the important principles to follow are: (*a*) Use as little light as possible, (*b*) use it for as brief a period as possible, and (*c*) use red light, which will permit useful vision without destroying dark adaptation. A red flashlight having many uses may be improvised by inserting a disc cut from the red plastic lens of the Navy dark-adaptor goggle. This may be used with discretion for reading maps, instruments, etc., at night without impairing dark adaptation. Even red light, however, should be as dim as possible, or completely shielded, to reduce the danger of detection by the enemy and also to prevent the impairment of night vision by the phenomenon of glare.

Contrast.—Night vision is colorless vision and is, therefore, wholly dependent on contrast. Objects can be seen only if they are lighter or darker than the background. Hence, anything which reduces contrast, such as haze, fog, dirty or scratched windshields or goggles will seriously impair night vision. It is important, therefore, that such surfaces be kept scrupulously clean.

Night Binoculars.—The casual use of any binoculars for night work may cause serious reduction in night vision. Only night binoculars which transmit sufficient light to give, on the one hand, magnification, and on the other, no appreciable decrease in illumination, will aid night vision. With this type of binocular, night vision is improved by virtue of the fact that the increased size of the image on the retina causes a proportional increase in the number of light receptors stimulated.

Diet and Vitamins.—Prolonged shortage of vitamin A will result in impaired night vision. However, on the adequate diet which is provided generally throughout the Navy, no such shortage will result. Vitamin A or its precursor, carotene, occurs in fresh vegetables, green salads and fruits, milk, cream, butter, cheese, eggs, meat, liver, fish, whole-grain cereals, and nuts. On submarines, small ships, or long cruises where adequate supplies of fresh stores cannot be carried, vitamin preparations can be supplied by medical officers or hospital corpsmen to make up for shortages in the diet. Excessive or large extra doses of vitamins, more than one would get in a liberal well-balanced diet, will not improve night vision above normal.

Oxygen.—Night vision is one of the first faculties affected adversely by lack of oxygen at altitudes above 6 to 8 thousand feet. Unless oxygen is used, instrument markings will seem dimmer and the pilot may turn up panel lights more and more brightly, thus starting a vicious cycle, with resultant serious impairment of visual efficiency. Use of oxygen in night flying, therefore, should begin at lower altitudes than in daytime or at ground level.

Glare.—Light of any color, red or otherwise, will impair night vision if one tries to see above or beyond it, or to see while the light source is somewhere within the field of vision. This is known as glare. With glare from red light, dark adaptation will not be effected and full night vision will be available when the glaring source is removed; but until it is removed there may be considerable impairment of night vision. Dim fluorescent lighting, such as is used to illuminate instruments or aeronautical charts, may cause an impairment of one to two hundred percent if the light is left on as a glaring source. The important considerations in night illumination practice are that, if possible, the light should be red of the proper quality, should be dim, diffused, and have no glaring hotspots.

Night Lookout Technique.—Both the nature of rod vision and the distribution of the rods over the retina impose limitations on night vision. There are only cones in the fovea centralis or visual center of the retina. This is the point of sharpest vision in the light-adapted eye (day vision), and one's attention is habitually fixed on objects so that their images are thrown on this small area. But in dim illumination, such as occurs at night, this rod-free area, the fovea, is blind; and central, or direct, vision cannot be used. The eyes must be used in a different manner. The gaze must be directed slightly above, below, or to the side, so that the image of any object one wishes to see will fall on a portion of the retina where there are rods. This technique of night-seeing has been called parafoveal vision, peripheral vision, or using "the corners of the eyes." This technique of using peripheral vision is one of the most important practices in achieving effective night vision. It does not, however, come naturally and must be conscientiously practiced. Another important practice in night-lookout technique is called scanning. The eyes should be moved frequently while in dim light. The eyes are most sensitive just after being moved. They should be moved in short jumps to search the sky or horizon systematically and hence, to be made aware of objects in the periphery of the eye. Figure 2 illustrates diagrammatically correct night-lookout technique, using peripheral vision or the "corners of the eyes".

Fatigue, Distraction, and Discomfort.—Night-visual efficiency is impaired by fatigue, distraction, and discomfort. The impairment may be the result of a generalized lowered level of efficiency, or the impairment may be due to moments of abstraction, loss of attention, or an unawareness of objects in the visual field, "staring into space", or "doping off". The greatest factor in combating the adverse effect of fatigue, distraction, and discomfort is the maintenance of a high degree of motivation, which is a necessary requirement for maximum night-visual efficiency. One must first know one's job, and secondly, want to do one's job to such a high degree that one is on the alert at all times to the enemy one is trying to see at night. Specifically, all efforts should be made to allay physical fatigue, to remove distracting objects, distracting lights, or distracting thoughts, and to allay discomfort due to inadequate or unsuitable clothing and other irritating factors.

Drugs.—The sulfonamides definitely impair retinal sensitivity and hence, night vision. No one taking a full course of sulfonamide therapy should stand night-lookout duty or other night duty.

Elements of Night Vision and the Testing of Retinal Sensitivity.—Good night vision in combat personnel is one of the most important factors in modern warfare. For this reason, a great deal of stress has been placed on the selection of those with good night vision and on the training of them for duties at night requiring good night vision. Night vision as a whole depends on six main

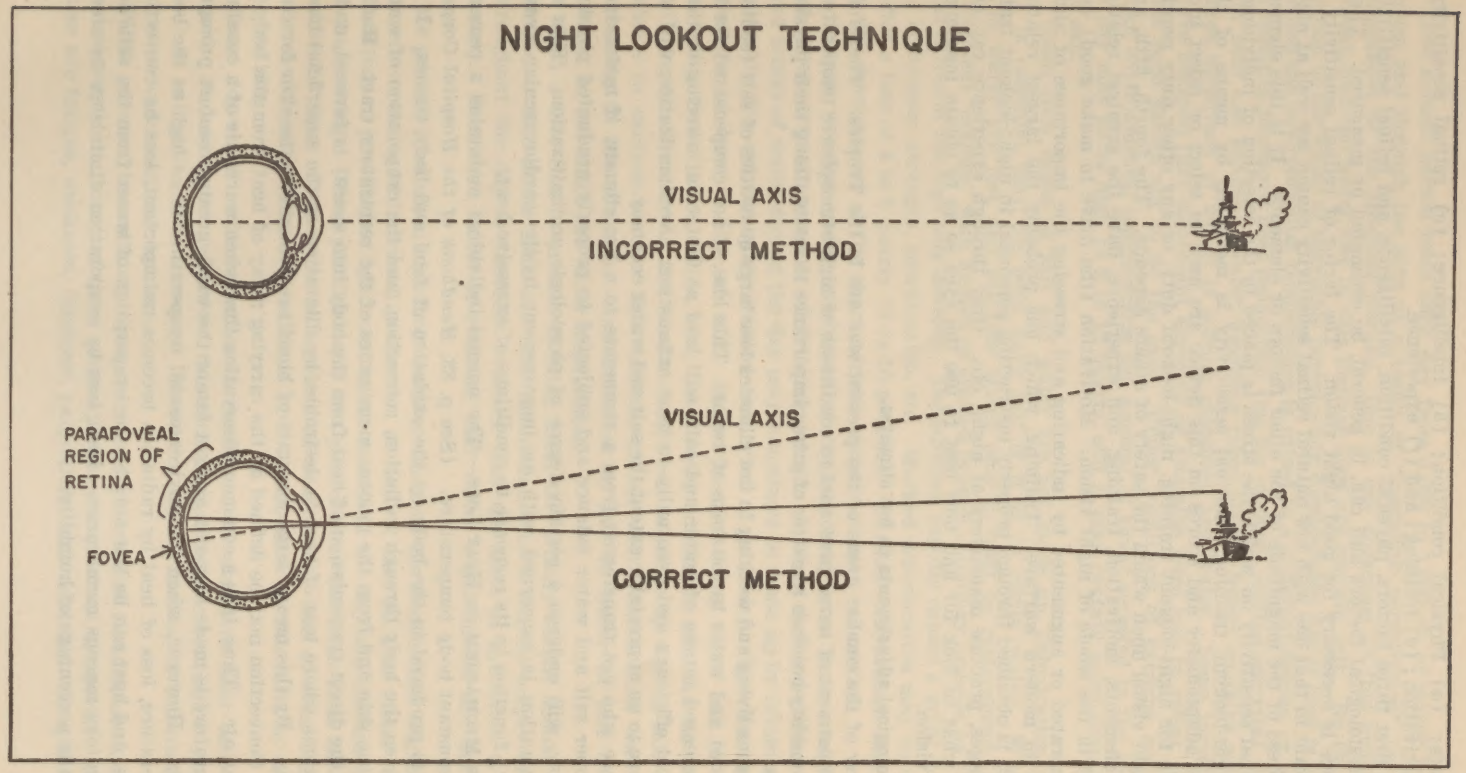

FIGURE 2.—Practice use of the "Corners of the Eyes"—night targets are better seen by *not looking directly at them.* This is because the edges of the retina (parafoveal regions or periphery) are more sensitive to dim light than is the very center of the retina (fovea centralis).

elements: (*a*) Physical condition; (*b*) intelligence; (*c*) retinal sensitivity; (*d*) motivation; (*e*) training; and (*f*) experience.

The first three factors, physical condition, intelligence, and retinal sensitivity, are physiological factors and can, in general, be estimated or measured. Their presence is necessary for good night vision. The factor of retinal sensitivity is important in that one with low natural retinal sensitivity cannot see well at night regardless of the magnitude of the other factors or elements. It is this element of retinal sensitivity on which the stress is placed in the selection of individuals for night-lookout training. Retinal sensitivity is measured by means of the Navy's adaptometer and scores on this device are used to select or reject individuals for night-lookout training, night-lookout duty, or any other duty requiring night vision upon which the safety of others depends. The fourth, fifth, and sixth elements, motivation, training, and experience, have the greatest relative weight in the whole of night vision. Motivation (the drive to make good) can be generated or augmented by indicating and stressing the importance of night vision in modern warfare. Training, which has probably the largest relative weight, is obtained through properly instructing personnel in night-lookout training stages, practice maneuvers at night, etc. Only through experience can one learn what to look for and how best to use the eyes so as to obtain maximum night vision.

Physiological adjustments in hot climates.

Many of the combat areas of the present war are in the Tropics. Therefore, the adjustment of naval personnel to conditions of high atmospheric temperature and humidity becomes a matter of prime importance in maintaining their physical fitness.

Persons living and working in hot climates lose large quantities of salt (sodium chloride) and water in the form of sweat. This loss, if not compensated for by an increased intake of water and salt, will lead at first to a lowering of their physical efficiency and eventually to heat exhaustion. Acclimatization will not improve to an appreciable extent the salt and water economy.

Those who are transferred from a temperate to a hot climate, if maintained in proper salt and water balance and subjected to properly graduated physical activity, will undergo a certain degree of physiologic acclimitization. This acclimatization is concerned with an improvement in the cardiovascular (vasomotor) function in its response to conditions of excessive heat.

THE MECHANISM OF HEAT LOSS.—The normal individual maintains a remarkably constant body temperature. (See p. 83, *Handbook of the Hospital Corps.*) Heat is produced in the body by the oxidation of food and body tissues. It is lost from the body through radiation, convection, and the evaporation of water from the skin and from the mucous membranes of the respiratory tract. Radiation (the direct transmission of heat from the body into space) is favored, under conditions where loss of heat is desirable, by dilatation of the superficial blood vessels. By this means large amounts of blood are brought to the skin for cooling. Convection may be defined as the carrying away of heat from the body by moving air. Thus, it is a common observation that when warm air of a constant temperature is made to move, as by a fan or the wind, greater comfort promptly results. However, when the environmental temperature is as high as the body temperature, loss of heat by radiation becomes unimportant, loss by convection ceases, and heat can be lost only by the evaporation of water from the skin and respiratory mucous membranes. Heat loss by evaporation diminishes inversely with the percentage of humidity.

The normal person loses each day from 1,000 to 1,500 cc. of water from the lungs and through the skin as a result of "insensible perspiration" (see p. 68, *Handbook of the Hospital Corps*). One is not conscious of this moisture as sweat, and the water lost in this manner does not contain salt. By the evaporation of the water of insensible perspiration considerable loss of heat is effected. When the environmental temperature is raised to a sufficient degree, or when as a result of increased heat production (as, for example, during exercise) the need for heat loss becomes greater, sweating takes place. Sweat contains salts (the most important of which is sodium chloride) and water. Some investigators have believed that significant amounts of vitamins were lost in sweat, but this has been shown not to be the case. Under conditions of extreme activity at high environmental temperatures the amount of sweat secreted in the course of a day may be as high as 8 to 12 quarts, and it may contain more than 20 Gm. of salt.

When such losses of salt and water are not made up, dehydration results. It is essential that the body have salt if it is to retain water. When salt and water are lost and salt-free water only is used in replacement, gastrointestinal "cramps" with nausea or cramps in such voluntary muscles as those of the calves of the legs may develop. Dehydration rapidly causes a great decrease in endurance, strength, coordination, etc. Marked deterioration may be evident after a loss of 4 to 5 quarts (8 to 10 pounds). Further dehydration may result in the development of the characteristic picture of heat exhaustion.

Persons working under conditions of tropical heat must have available at all times adequate amounts of drinking water. A slight deficit between output and intake of water during the day may sometimes be made up by drinking more water in the evening when resting and when it is cooler. The average diet contains at least 5 Gm. of salt. By purposely adding extra salt to foods, including fruit juices, soups, etc., the dietary intake of salt can be doubled. Still further increase in the intake of salt can be made by adding salt or salt tablets to canteen water. Salt tablets, unless well diluted with water, are irritating to the stomach. Concentrations of salt in water of less than 0.9 percent do not make the water unpalatable.

When a diet rich in protein is being used, the urinary output should not be allowed to fall below 1,000 cc. The maintenance of a normal output of urine throughout the day is excellent evidence that the state of hydration is satisfactory. Persistent thirst is evidence that water requirements are not being met.

As protein food when absorbed tends to increase the metabolism slightly and therefore results in increased production of heat, it may be wise under tropical conditions to provide the light meal in the middle of the day and the heavy meal in the evening. When practicable, a rest period after the noon meal should be enforced. Loss of heat can be accelerated and thereby loss of vital fluid and salts saved under extreme conditions such as exposure on life rafts by wetting the clothing.

Some degree of acclimatization to conditions of excessive heat can be attained. As was mentioned before, this acclimatization does not include improvement in salt and water economy. However, acclimatization is retarded by a negative water and salt balance.

When persons, immediately upon transfer to a tropical climate, are required to do heavy work, many of them may experience unpleasant symptoms. Among these are fatigue, weakness, dizziness, palpitation, and vomiting. In addition it

will be found that they have elevated body temperatures and a tendency to rapid heart rate and low blood pressure when up and about. By subjecting them to at first small but gradually increasing amounts of physical activity, these symptoms can be avoided and increasingly heavy work performed without their development. Acclimatization takes place, therefore, in the physiological responses of the body especially with respect to the vasomotor system and the regulation of body temperature. Such acclimatization may be lost after 3 or more weeks' withdrawal from the hot climate or from physical activity.

MINOR SURGERY AND FIRST AID

SHOCK

This condition, which has been defined as "a depression of the vital functions of the body," is present in some degree in all serious injuries, especially those occurring in war, and must be considered in their treatment.

Shock generally is described as *primary* and as *secondary*. The importance of primary shock has probably been overemphasized. It is a nervous reaction, in the causation of which fear plays a prominent part, and ordinarily is not a threat to the life of an individual. It is more properly called syncope, or fainting. While it frequently follows war wounds or burns, it may also, in susceptible individuals, follow a hypodermic injection, the sight of blood, or the receiving of some bad news. Secondary (traumatic) shock, on the other hand, may appear soon after injury or not until after several hours. It is a serious threat to the life of the individual.

Cause.

Many theories have been advanced as to the cause of shock but none offers a completely satisfactory explanation. It is known, however, that in all types of shock the major factor is a reduction in circulating blood volume. Conditions in which there is excessive fluid loss therefore favor the development of shock. Such conditions include internal or external hemorrhage, the enormous loss of plasma from the surface of burns, the swelling which so often occurs in injured limbs, and acute water and salt loss such as often occurs in diarrhea or vomiting. In certain types of wounds the local loss of plasma or blood does not account for the loss in blood volume, and various investigators have attempted to show that blood is lost or trapped in distended veins or capillaries in various parts of the body or that the capillaries generally allow plasma to escape through their walls into the tissues, but at the present time there is no proof that any such thing happens.

When the volume of circulating blood is reduced, the body makes an attempt to prevent the consequent fall in blood pressure by narrowing the blood vessels. However, this defense mechanism cannot be maintained for long, and after a variable time the blood pressure falls. The circulation becomes slowed to a point where the blood may remain almost stagnant in the capillaries. A constant supply of oxygen is necessary to the normal functioning of all parts of the body and this failure of the circulation deprives the tissues of the required oxygen, and there results a serious depression of all vital functions.

Symptoms.

In primary shock (or syncope) there may be momentary pallor, general weakness, unconsciousness or mental confusion, normal or slowed pulse, slightly lowered blood pressure, and sweating. The symptoms usually are of brief duration.

In secondary (traumatic) shock the skin is pale, covered with cold sweat, and feels clammy; the pulse is rapid, feeble, and fluttering; the respirations are rapid and shallow and mixed with sighing because of air hunger; the hands and

feet are cold; the tips of the fingers and toes and the lips and ears may be cyanotic; the patient is restless, very thirsty, anxious and perhaps mentally dull; the pupils generally are dilated; the temperature is subnormal; the blood pressure is very low; and there may be nausea or vomiting.

Treatment.

It was stated in discussing the cause of shock that when the volume of the circulating blood begins to decrease, the body makes an attempt to prevent the consequent fall in blood pressure by narrowing the blood vessels. A patient who has received a severe injury which will probably result in shock may, therefore, when first seen, have a normal blood pressure. In many instances the administration of plasma at this stage will prevent the development of shock. Consequently, it is essential that every casualty receive plasma, whether or not the blood pressure is low, if the injury is of sufficient severity to probably result in shock.

The emergency treatment of shock requires:

(*a*) Placing the patient in the proper position;
(*b*) Keeping the patient warm;
(*c*) Administering morphine;
(*d*) Stopping hemorrhage;
(*e*) Replacing of volume of circulating fluid; and
(*f*) Splinting of fractures.

POSITION.—Place the patient in a horizontal position and if possible in one where the lower part of the body is higher than the head. The circulation in shock is very unstable and placing the patient in the position specified provides for a flow of blood to the brain, the organ that is most susceptible to deprivation of oxygen. Elevation of the head or upper part of the body, by decreasing the blood supply to the brain, may be very dangerous. Many patients in shock are restless and mentally confused and will try to get up. It is therefore necessary to watch to see that the patient stays in the position in which placed.

WARMTH.—Keep the patient comfortably warm and if cold wrap in a blanket. A warm drink may be given if the patient is conscious. Do not warm the patient by hot-water bottle or other artificial means for by warming the skin the surface vessels are dilated and blood is drawn to the skin away from vital centers. In shock the tissues suffer from a lack of oxygen and the application of heat increases the requirements of the tissues for oxygen.

MORPHINE.—If the patient is conscious give 0.015 Gm. (or ¼ grain) to 0.03 Gm. (or ½ grain) of morphine by hypodermic injection. (One morphine syrette contains ½ grain.) If the restlessness continues or returns, or the pain is not relieved, 0.015 Gm. (or ¼ grain) of morphine may be given by hypodermic injection (or one-half the contents of a morphine syrette) every 2 to 4 hours. Patients in shock sometimes vomit and the vomiting may occur because of overdosage with or idiosycrasy to morphine. When there is vomiting lay the patient face down so that vomitus will not be inhaled into the air passages and the lungs. Usually if the patient has received too much morphine the respiratory rate will be slowed (under 15 per minute) and the pupils of the eyes will be small (pin-point). Patients with head injuries who are conscious should not be given more than ¼ grain of morphine as a single dose.

HEMORRHAGE.—Bleeding must be stopped at once by use of the methods described in the section titled Wounds. The control of hemorrhage takes priority over plasma administration.

FLUID VOLUME. — *Plasma.* — Administer plasma promptly and in adequate amounts. Because the fundamental disturbance of physiology in shock is re-

duction of circulating blood volume, the logical treatment of shock therefore includes restoration of the blood volume to normal. In most circumstances the ideal fluid for this purpose is whole blood, but as whole blood is difficult to preserve and supply under combat conditions, recourse usually is had to blood plasma which is blood from which the red blood cells have been removed. Be sure to give enough plasma. In severe shock start with at least 1,000 cc., giving it fast, and then continue to administer plasma until the blood pressure and the volume of the pulse have returned to normal.

Fluids.—Under conditions of battle many men are dehydrated. Plasma or serum albumin tends to restore to normal the blood volume by drawing water from the tissue spaces into the blood stream. Therefore, further tissue dehydration takes place. It is essential then, that fluid be given. Water is retained better if salt is added to it. It has been found that physiological saline solution is of great value in shock whether administered by mouth or administered by vein. It should be given, when available, as an adjunct to plasma therapy and is particularly valuable when plasma is not available. For oral use, salt tablets may be added to the water in canteens.

Splinting of Fractures.—Fractures must be immobilized by splints before moving the patient. If fractures are not splinted before the patient is moved, the jagged ends of the broken bones will cause additional damage to tissues and recovery from shock will be delayed.

If burns are present sterile pressure dressings should be applied over petrolatum to the burned areas so as to slow fluid loss.

Any wounds present should be dressed. When wounds of the extremities are extensive, even in the absence of fractures, splints should be applied.

WOUNDS

The definition of wound appears on page 93 of the *Handbook of the Hospital Corps.*

Wounds generally are described as *clean* or *aseptic* when no infective microorganisms have gained access to them, as *infected* or *septic* when infective microorganisms have been introduced into them. They also are known as *incised*, *lacerated*, *contused*, *punctured*, *crushed*, and *gunshot* according to the characteristics of the wounds or of the force causing them. All battle wounds must be presumed to be infected

The healing of wounds may be prevented or delayed because of infection, the presence of foreign bodies, poor circulation of the blood, etc.

Wounds are accompanied by external or internal hemorrhage and sometimes by both, usually by shock, and frequently by fractures. They readily become infected.

Treatment.

The emergency treatment of wounds requires the immediate stopping of hemorrhage, the treating of shock, the taking of measures to prevent or to combat infection, the application of dressings, and the splinting of fractures if present.

Hemorrhage must be promptly controlled. Bleeding from capillaries (oozing) or from veins (steady flow) is usually controlled easily by means of a compression dressing and elevation of the part. The local application of cold may aid by reducing the blood flow but heat should not be applied as it increases the flow of blood.

Blood coming from a severed artery usually flows in spurts. Arterial bleeding must be promptly stopped and usually it is sufficient to pack the wound with sterile gauze and apply a pressure dressing. Sometimes pressure must be applied over the course of the artery leading to the part. When a bleeder is visible it should be ligated.

Arterial bleeding in a wound of an extremity can be stopped by applying a tourniquet above the bleeding point and tight enough to stop the circulation in the entire limb beyond the tourniquet. It should be emphasized, however, that *the use of tourniquets is extremely dangerous* and may lead to loss of the limb from gangrene. Furthermore, their use may increase shock for one of the methods of producing shock in experimental animals is the continuous application of a tourniquet for several hours. In arterial bleeding a tourniquet should be used only as the last resort, all other methods for controlling the hemorrhage having failed. If a tourniquet is used, it should be loosened every 20 to 30 minutes and if on loosening the tourniquet bleeding starts again, it may be tightened again. A tourniquet should not be covered with a bandage or splint as it may be overlooked or forgotten.

When in the opinion of a medical officer a limb has been so badly injured that amputation cannot be avoided and hemorrhage is severe, a tourniquet may be applied. Under these circumstances, however, it should *not* be loosened until after the amputation has been performed.

Shock should be treated as described in the section under that title.

Infection of wounds must be prevented and combatted by cleansing, by applying dressings and bandages, and by the use and administration of sulfonamides or penicillin.

Cleansing a wound imperfectly is, theoretically, worse than no cleansing, for imperfect or careless cleansing may introduce additional contamination into the wound, may cause additional damage to the already injured tissues, and may increase shock. When cleansing a wound it must be handled so as not to introduce infective bacteria; all foreign bodies such as dirt, bits of cloth, pieces of metal, loose pieces of dead tissue, etc., that may be *near the surface* of the wound should be removed; using sterile forceps if possible; and any free grease or oil that may be present about the wound should be gently wiped away. The removal of grease and oil is not a necessary procedure in cleansing a wound for the reasons that bacteria ordinarily will not multiply in either one, that oil and grease will not adhere to wet surfaces in a wound, and that both are gradually washed away by exudate from a wound and taken up by the dressings.

Infection in wounds is best prevented or combatted by use of the sulfonamide compounds internally.

Sulfadiazine pills should be given to the patient who should chew and then swallow them, aided with small sips of water if it is available. The pills should not be given to an unconscious person nor to one who has a serious injury of the mouth, throat, or stomach such as would hinder or prevent swallowing.

The value of local application of the sulfonamides is a matter of controversy. It is possible that it helps to retard the development of infection in wounds that may have to wait some time before being treated by a medical officer. Too much reliance should not be placed in this practice, but in the light of present knowledge it is wiser to continue it.

The sulfanilamide crystals may be used in the treatment of all kinds of wounds, including those of the brain, eyes, lungs, abdomen, bones, and all soft tissues.

After checking hemorrhage and cleansing the wound, sprinkle sulfanilamide crystals thinly and evenly over the entire surface and into the depth of the

wound, being careful not to dump them in a heap in one spot. The wound is now ready for the application of a dressing.

Patients who have taken sulfonamide pills should be encouraged to drink freely of water and other fluids. A free flow of urine (1,000 cc. or more daily) may prevent kidney damage from the formation of sulfonamide crystals in the uriniferous tubules.

The individual first-aid packet now being issued contains an envelope in which there are 5 grams of sulfanilamide crystals in addition to the sterile compressed bandage. Issued with the first-aid packet is a small carton containing two 2-gram pills of sulfadiazine, peppermint flavored, which is to be carried in the same pouch with the first-aid packet in the web belt. There are thus available for immediate use by an individual wounded in combat the necessary sulfonamides to give protection against infection, as well as the sterile dressing. The odor of peppermint on the breath of a wounded person should be considered as indicating that the sulfadiazine pills have been taken, even though a dressing may not have been applied.

All sulfonamides administered by medical-department personnel serving in the field in treating the wounded must be accurately recorded on the Emergency Medical Tag.

Immunization of all Navy and Marine Corps personnel against tetanus is required. Alum-precipitated tetanus toxoid is used for this purpose. A routine "booster" or stimulating immunization against tetanus is required 1 year after the initial immunization and every 4 years thereafter and, when possible and irrespective of the time interval since previous injection, before going into a combat zone. In addition to the initial and the routine "booster" injections, an emergency "booster" immunization, consisting of 0.5 (½) cc. of alum-precipitated tetanus toxoid given intramuscularly, shall be administered immediately to: (*a*) Each individual who incurs a wound or severe burn in battle; (*b*) patients undergoing secondary operations or open manipulations when, in the opinion of the responsible medical officer, there exists the possibility of contamination with tetanus organisms; and (*c*) individuals who incur punctured or lacerated nonbattle wounds, powder burns, or other conditions which might be complicated by the introduction of tetanus bacilli.

Dressings consist of everything used to cover or dress a wound and their purpose is to stop hemorrhage, to prevent introduction of bacteria, and to prevent further injury to the wound. Dressings should be applied as soon as possible. Dressings are secured by bandages applied tightly enough to keep the dressings in place and produce some compression but not so tightly as to produce constriction of blood vessels unless their purpose is to prevent arterial hemorrhage.

Splinting of any fracture present must be done after a wound is dressed. Severe wounds of the soft parts also should be splinted.

For immobilization of fractures any material that has sufficient firmness to give support to the broken bone or bones and keep them from moving may be used in emergency.

Traction is not usually necessary in fractures of the bones of the upper extremity, immobilization generally being sufficient, but fractures of the bones of the lower extremity usually require traction, to prevent overriding of fragments, as well as immobilzation.

Certain types of battle wounds require special treatment.

In *wounds of the face* when the lower jaw is shot away the tongue loses its anterior points of fixation and may fall back into the throat and choke the

patient. If this occurs, a safety pin may be put through the middle of the tongue, closed, and a thread or cord attached to it, or a thread may be put through the tongue with any kind of a needle, so as to provide for a forward pull on the tongue. Such forward traction on the tongue will also, at times, aid in controlling hemorrhage from the root of the tongue. Patients with face wounds should be evacuated with the face down.

All *head wounds* and *wounds of the scalp* should be considered as serious. If time is available, the hair about such wounds should be cut off with scissors, sulfanilamide crystals introduced, and a snug compression bandage applied. Notes as to the patient's condition, such as state of consciousness, paralysis of limbs, etc., made at time of dressing and sent along with the patient will be of aid to the surgeon giving treatment later on. These patients also should be evacuated with the face down.

Large, *sucking wounds of the chest*, where air rushes in and out through the opening with each respiration, cause marked shock and death unless early care is given. Such wounds must be closed with any means at hand if the patient is to live. Wounds of this type may be closed by packing with sterile gauze (preferably soaked with petrolatum), by pinning the edges together with safety pins or by sewing them together with any needle and thread available, even by stuffing the patient's shirt into the wound, etc. After closing the wound a dressing should be applied.

On board ship, under wartime conditions, the use of *cotton thread as suture material* has been found to be both practical and desirable. Catgut may not be available under certain circumstances but cotton thread is almost always obtainable from small stores or the sailmaker in at least two sizes.

Cotton sutures produce practically no local reaction in wounds, the ends are not stiff and do not catch when gauze dressings are removed, and the knots are easily tied and remain tight.

As there is a certain amount of shrinkage when cotton suture material is autoclaved, the cotton thread should be wound on a piece of gauze before autoclaving to prevent rupture of some of the fibers with resultant weakening of the suture.

Patients with *wounds of the abdomen* must be evacuated ahead of all others as they must be operated upon as early as possible to effect permanent control of hemorrhage and to prevent probable fatal peritonitis. Sulfanilamide crystals should be sprinkled into the wound and a dressing applied. Abdominal wounds should never be probed in an effort to remove metal fragments. If such fragments are superficial and can be readily seen they may be removed. Do not try to remove damaged intestine. All cases with penetrating abdominal wounds should receive ½ grain of morphine and not too much time should be wasted in attempting to overcome shock before evacuating the patient.

Morphine.

With respect to the administration of subsequent doses of morphine there are no fixed rules to follow and therefore one must be guided by the observed tolerance of the patient for the drug and by its known toxic effects.

Individuals vary markedly in their tolerance for this drug. Curiously enough, tolerance for morphine varies somewhat with the need; for example, a person in great pain can tolerate larger doses than a normal individual. Some persons have an idiosyncracy (react abnormally) to the drug and cannot tolerate even minimal doses without the development of unpleasant toxic effects.

The toxic effects of morphine in the treatment of battle casualties are: (1) Depression of the depth and rate of respiration through a direct effect on the respiratory center of the brain; and (2) production of nausea. The occurrence

of either of these toxic symptoms is usually associated with contraction of the pupils of the eyes, which may be very marked and is a valuable warning of overdosage. It is because of its depressant action on the respiratory center that morphine must be given cautiously to patients with injuries of the brain or chest. In administering subsequent doses of morphine one should be guided on the one hand by observation of the need of the patient as demonstrated by pain and restlessness and on the other hand by observation of the patient for possible symptoms of overdosage, especially slowing of the respirations, contraction of the pupils, and nausea. Even in seriously injured persons, ¼ grain of morphine every 2 hours represents maximum safe dosage except in rare instances.

Air Evacuation of Wounded.

Reports from the battlefronts indicate that great benefit has accrued from the use of air evacuation of battle casualties. It should be stressed, however, that where adequate care is available, seriously wounded men should not be evacuated immediately after operation.

Two types of cases are adversely affected by travel by air. The first is the patient who has recently undergone an abdominal or intestinal operation. The peristaltic action of the bowel in such patients is weakened as a result of the trauma to the intestine or the presence of inflammation of the peritoneum, and gas tends to accumulate in the loops of the intestine, producing distention. The second is the patient who has pneumothorax, a condition in which air has gained access to the pleural cavity.

In either type of case the trapped air, or gas, will frequently expand at high altitudes with the decreased atmospheric pressure to a degree that may endanger the welfare if not the life of the patient.

Gas Gangrene.

Gas gangrene is the most dreaded infectious complication of war wounds. The bacteria which cause it are the spore-forming, anaerobic, Gram-positive bacilli known as *Clostridia*. They are normal inhabitants of the intestinal tract of man and of domesticated animals. They may persist as spores for long periods in the ground, especially where manure has been used for fertilizer, and in street dirt. It has been observed that clothing is an even more important source of gas-gangrene infection than is soil. Experiments have shown woolen clothing to contain gas-bacilli in most of the samples tested, while cotton and silk are much less frequently infected.

The *Clostridia* are all toxin producers. Those most likely to produce gas gangrene are: *Cl. welchii*, *Cl. septicum*, and *Cl. oedematiens*. (See p. 95, *Handbook of the Hospital Corps.*)

Because fatal gas-bacillus infection may become established with great rapidity, early recognition is important.

The *Clostridia* of course are present in a great many war wounds without producing gas gangrene. The conditions favorable to their causing a serious infection are those in which the wound contains devitalized tissue, especially muscle of which the blood supply has been damaged.

Gas-bacillus infections which involve only the damaged subcutaneous connective tissue are usually mild, while those which become established in devitalized muscle are apt to be grave. The *Clostridia* as they multiply in such muscle develop great virulence and invasive power and eventually attack healthy tissues as well. As all of the gas bacilli produce a soluble toxin, the systemic reaction may be profound.

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Local signs of gas gangrene include pain, gas, and odor. Gas is evidenced by fine creptius (crackling sensation) on palpation about the wound, or by bubbles expressed through the exudate. The odor is usually putrid when subcutaneous tissue is involved, and "mousy" when the infection has become established in muscle.

General signs include an abrupt rise in the pulse rate, blood pressure, and temperature in persons of good resistance, while in overwhelming infections there may be subnormal temperature with rapid, thready pulse.

PREVENTION.—(1). Careful excision by a medical officer of the devitalized tissue in wounds, attention being paid especially to muscle, the blood supply of which has been lost.

(2). Avoidance of primary suture of wounds.

(3). Oral administration of sulfonamides to all seriously wounded patients. (While the results of treatment of already established gas gangrene with the sulfonamides have been disappointing, there is general agreement that a satisfactory sulfonamide level heightens the resistance of normal tissue to invasion by the *Clostridia*.)

(4). The administration of 2 to 3 standard doses of the polyvalent gas-bacillus antitoxin (Supply Catalog item S1–1000), to patients with wounds involving extensive damage to muscle.

TREATMENT.—*General.*—(1). Continuation of sulfonamide in dosages sufficient to maintain an adequate blood level.

(2). Repeated administration of large doses of gas-bacillus antitoxin.

(3). Early experimental work with penicillin suggests that this drug is effective against the pathogenic *Clostridia* and may prove to be of great clinical value.

(4). Supportive treatment including transfusions of whole blood, if available, otherwise plasma.

Local.—When proper surgical care is obtainable, wide extirpation of devitalized muscles may have to be carried out and, in some cases, amputation of the affected limb.

INJURIES DUE TO HEAT AND COLD

Burns

Naval warfare results in many casualties from burns. The present war has brought some increase in the knowledge of the pathology and altered physiology involved in burns and great improvement in and simplification of their therapy.

There are many classifications of burns. The *Handbook of the Hospital Corps* differentiates between burns and scalds on a basis of whether or not the hair is removed and states the treatment is the same for both. It mentions burns of first degree (redness), second degree (blisters), and third degree (charring). The extent of a burn may be described by saying that a certain percentage of the body is involved and burns may be considered minor or major according to the area affected. (Relative skin areas are shown in figure 3.) A knowledge of such classifications is of minor importance as compared with an understanding of the principles underlying the therapy of all burns. This discussion of burns will be limited to those of sufficient degree to involve the danger of shock.

Treatment.

The therapy of burns may be subdivided into (A) general treatment of the burned patient and (B) local treatment of the burned surface.

A. General Treatment of the Burned Patient comprises:

1. The Prevention and Treatment of Shock.—Early death in severely burned patients is almost always due to shock. Burned areas do not ordinarily bleed but they freely exude plasma. Consequently the plasma loss is relatively greater than the blood cell loss. The loss of plasma produces the reduction in circulating blood volume that is a major factor in causing shock. The fluid lost from the circulating blood must be replaced and plasma is the ideal replacement fluid.

RELATIVE SKIN AREAS ACCORDING TO BERKOW

ADULTS		CHILDREN	
TRUNK	38 %	TRUNK	40 %
LOWER EXTREMITIES	36	LOWER EXTREMITIES 12-AGE IN YEARS	38
UPPER EXTREMITIES	18	UPPER EXTREMITIES	16
HEAD	8	HEAD 12-AGE IN YEARS	6

BERKOW'S METHOD OF ESTIMATING EXTENSIVENESS OF SKIN LESIONS

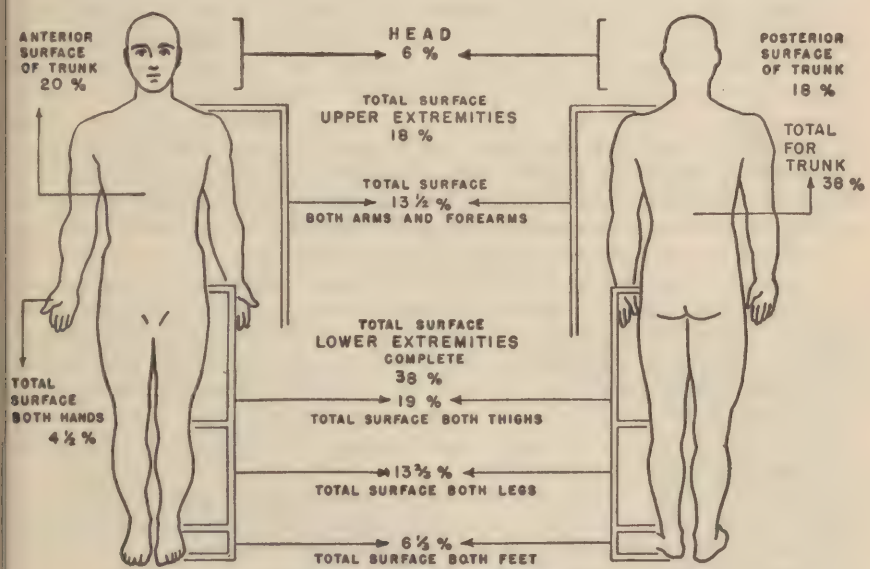

Figure 3.—Relative skin areas.

It must be given early and in adequate amounts. If, in cases seen immediately after injury, shock is not fully developed, plasma should be given to prevent shock. If shock has already developed, the first 500 to 1,000 cc. should be given rapidly. It is important that plasma be given continuously. A good "rule of thumb" to follow in administering plasma is to give 100 cc. for every 1 per cent of the body surface burned.

All of the other measures for the prevention or treatment of shock in burn cases should be employed, i. e., position with head lowered, morphine, prevention of excessive loss of body heat, etc.

2. The Prevention of Sepsis.—Burned tissues are excellent culture media for bacteria. Among bacteria the most dangerous to the burned individual is the *Streptococcus hemolyticus* which, because of its invasive tendencies, tends to produce a spreading infection, eventually involving the blood stream. This serious complication is best prevented by the oral or parenteral administration of sulfonamides for the purpose of making the tissues and fluids of the body resistant to infection. As soon as possible after being burned the patient should be given 4 Gm. (or 60 grains) of sulfadiazine by mouth (intravenously if unable to swallow). The subsequent dosage should be 1 Gm. (or 15 grains) every 4 hours until the patient is brought under the care of a medical officer.

3. Subsequent Care.—The subsequent care of a burned patient usually is under the direction of a medical officer but it may devolve upon hospital corpsmen on independent duty to see burned patients through a considerable period of their illness.

The loss of fluid from the burned area may be great and relapse into the condition of shock may occur even some time after the burn. Therefore it is important that the patient's blood pressure, pulse, and general appearance be observed at frequent intervals and that plasma be given continuously or intermittently until all danger of this complication is passed, which may be a matter of 2 or 3 days. Fluids other than plasma must be given by mouth, if possible; otherwise by vein.

A patient is not receiving enough fluid when, after recovery from shock, the amount of urine passed is not 1,000 cc. or more per day. Salt is essential in replacing the sodium and chloride lost through the burned tissues, and the sodium ion in salt helps the body to retain fluid. Alkalies, as sodium bicarbonate or sodium citrate, should be given by mouth, when possible, to combat acidosis and to alkalinize the urine, and thereby help to avoid the formation of crystals in the kidney tubules, with consequent kidney damage, which sometimes occurs in sulfonamide therapy. The alkaline potassium salts should not be used as potassium administration favors the excretion of much-needed sodium.

Nutrition is of the utmost importance to prevent wasting of body tissues and to promote healing, and to help the body to combat infection. A minimum of from 100 to 300 grams of carbohydrate must be given each day and, when fluids have to be given intravenously, this can be added in the form of 5 or 10 per cent dextrose. The large amounts of protein lost through the burned area and by breakdown of body tissues must be made up. Ideally, a severely burned patient should receive 150 grams or more a day of protein, and when this cannot be given by mouth, the intravenous administration of plasma or a preparation of amino acids should be resorted to.

Finally, after the early stage of blood concentration caused by the loss of plasma is past, severly burned patients may rapidly develop a profound anemia, and this must be combatted by frequent transfusions of whole blood.

B. Local Treatment of the Burned Surface comprises:

1. Early Care.—Early local treatment of a burn is directed toward preventing infection and minimizing fluid loss. The application of tannic acid, or other eschar-forming substances, and coagulants which form surface crusts is no longer recommended. Infections are prone to develop under the tannic acid crust or eschar and the tannic acid which may be absorbed has been found to have toxic action on the liver.

Burns at the time they are received are bacteriologically clean. The burned surface, however, is a favorable medium for bacterial growth when organisms are introduced from the outside. Such organisms may be introduced from the patient's clothing or from the surrounding areas of skin, but most often they are introduced from the hands or the respiratory tracts of those who care for burned patients. The *Streptococcus hemolyticus* is most often introduced in this way. The local treatment of a burn therefore should be carried out under aseptic precautions and, if practicable, the operator or attendant should wear a sterile gown, rubber gloves, and a mask.

Especially where there has been gross contamination of the burned surface or where prevention of contamination seems unlikely, the local application of sulfonamides may have some value in preventing infection. Sulfanilamide may be applied but, as absorption from the burned surface may be very rapid, the total amount used should not exceed 10 grams. Greater reliance should be placed in the oral or intravenous administration of these drugs, as when administered by mouth or parenterally, a uniform blood and tissue resistance to infection will be provided.

Surgical removal (debridement) of dead tissue should not be attempted and blisters should not be broken. Fuel oil should be removed by gentle swabbing with petrolatum only if excessive amounts are present. Fuel oil is not irritating and may even be slightly antiseptic.

The whole burned area should be covered with sterile petrolatum. Then a bulky sterile dressing should be snugly applied, covering all the area burned. Large amounts of sterile gauze or cotton waste should be used and enough pressure applied to lessen the loss of plasma and, if there is bleeding, to control it. A splint should be applied where there is an extensive burn of an extremity. As the primary purpose of the dressing is to prevent contamination from without, it should be left in place for several days or until the patient is seen by a medical officer.

2. Late Treatment of Burned Area.—This is, in general, a problem for the medical officer. It is concerned with debridement of devitalized tissue, where necessary, the control of local infection, skin grafting, and measures to prevent contractures and other deformities.

Cold and Chilling

It is essential that all who may be exposed to severe cold be thoroughly indoctrinated in the methods of prevention, recognition, and treatment of frostbite and other adverse effects of such exposure. Lack of this knowledge and failure to provide adequate equipment have resulted in numerous unnecessary casualties and permanent disabilities.

The basic principles for prevention of injuries due to cold are (*a*) retention of body heat by insulation with suitable clothing and (*b*) maintenance of blood circulation in the extremities and all exposed surfaces. The best insulation is obtained by wearing inner garments of loose texture (containing many small air spaces) covered with an outer layer of tightly woven or impervious material. The insulating qualities of any clothing are almost completely destroyed by moisture. Neglect or ignorance of this fact has been the chief cause of serious injuries from cold. Sufficient circulation to prevent injury to parts of the body exposed to cold is promoted by exercise, by brisk rubbing of chilled (but not frozen) surfaces and by applying heat when this is available.

In extreme cold severe frostbite can occur without noticeable pain, particularly if the attention is distracted by other activities. Feel the ears, nose, and other

parts of the face and move the fingers and toes to be sure they are not numb. If the feeling is lost but the tissues are not stiff or grayish-white in color, circulation can be restored by brisk rubbing of the affected surfaces, by exercise, and by applying warmth with the hands or by placing the hands or feet inside a companion's clothing. The hands can be warmed by placing them in the armpits.

Exertion to the point of severe fatigue or exhaustion greatly decreases resistance to the effects of cold. Do not hesitate to go to sleep unless exhausted, painfully cold, numb, or unprotected. Sleep will increase resistance to the effects of cold and when one becomes chilled while asleep, one will wake and can then exercise to restore adequate circulation.

Recognition of injuries due to cold.

There is usually warning of impending frostbite or immersion foot by *pain in the affected area.* As already stated this may not be noted if the attention is taken up with urgent activity.

Immersion foot is *bluish in color and markedly swollen.* Frozen tissues are *grayish-white* and *stiff or rigid to the touch.* In both conditions *feeling and the ability to move the affected parts are impaired or lost.*

Treatment.

Frostbite.—Promote the drainage of venous blood by elevating the affected part and raising the temperature of the injured tissues *slowly.* If the feet are swollen, tight shoes will increase the damage by preventing circulation. Such footgear should be removed or cut away immediately. Cool water may be used to thaw the frozen tissues, but tepid or warm water or other applications of heat will greatly increase the injury.

Massage or bending of frozen tissues will cause additional severe injury. Therefore the affected areas must not be rubbed with snow or anything else.

When the tissues become warm, there may be very severe pain which may be relieved by morphine.

Keep affected extremities at rest, for any attempt to use them will make the condition worse. Even patients with lightly frostbitten feet are to be regarded as stretcher cases.

Large blisters commonly form on surfaces which have been injured by cold. These should not be punctured or broken and no attempt should be made to drain them excepting under medical supervision. If breaks appear in the skin, sprinkle sulfonamide powder from a first-aid kit on the area.

Care of injured personnel under conditions of extreme cold.—Measures for the prevention and treatment of additional injury by cold are the same as outlined in the preceding paragraphs with certain modifications and additional precautions.

It is obvious that wounded or injured men cannot be exercised to promote circulation and means must therefore be found to provide adequate covering and external warmth as soon as possible.

It must also be borne in mind that wounds or other injuries invariably result in some degree of shock which impairs the circulation and greatly reduces resistance to cold. Immediate care of such cases is therefore essential.

Severe injury by cold can occur without freezing the tissues or subjecting them to freezing temperatures. The best example of this is immersion foot or trench foot. This develops when crowded conditions, as in life rafts, or the necessity of standing for a long period of time in a trench or foxhole, prevent sufficient movement or exercise to maintain adequate circulation while the insulating capacity of footgear is destroyed by moisture.

Prevention of injuries by cold.

Suitable and adequate clothing, including at least one change of socks and underwear, should be provided. Footgear should be amply large to accommodate at least two pairs of heavy wool socks. It is better to use fewer socks than to impair circulation by tight footgear. If wet conditions may be encountered, it is essential that footgear and outer garments be waterproof.

Avoid wetting or moistening clothing. Do not walk in snow above boot tops. Do not sit or lie in snow. Brush snow off clothing before it melts.

If footgear or other clothing becomes wet under conditions of extreme cold, stop and change immediately. Frostbite is often insidious and will occur very rapidly with the combination of moisture and low temperature. If dry clothes are not at hand, a fire should be built and the wet materials dried out. Any dry covering such as wrapping in several layers of parachute canopy will provide more protection than wet socks or other clothing.

Under conditions that tend to cause immersion foot (temperature low but above freezing, wet feet, cramped position), tissue damage occurs more slowly but the end result is as serious as actual freezing. To avoid this type of injury the position should be changed and the feet elevated, dried, and covered whenever possible. Circulation should be promoted by exercises such as rising on the toes, moving the feet and ankles, or by shifting the weight from one leg to the other. Brisk massage of the legs in the direction away from the feet is also indicated.

When pressure bandages or a tourniquet are required to control hemorrhage, the circulation is reduced or cut off from the affected area. Insulation by bandages or other covering is of little value in such a situation and the part will chill and freeze very quickly unless heat can be supplied. In wounds of the trunk adjacent areas will supply this necessary warmth. Arms can be held close to the body and an injured leg with impaired circulation can be wrapped up with the opposite leg to supply some warmth. If the cold is severe, it is necessary to inspect the injured areas from time to time to see that they are not being further damaged by freezing.

Immersion Foot.—Observations of survivors of shipwrecked vessels have shown that they may develop incapacitating swelling and pain in their legs and feet. In contrast to actual frostbite, which occurs only after exposure to air at temperatures well below freezing, immersion foot develops when the feet are wet for a period of several hours or more in cold water. The severity of the process depends on the period of immersion, the degree of cold, and the protection afforded by wearing apparel or by greasing the skin. The swelling may begin at temperatures as high as 50° F.

The continued low temperature damages the walls of the capillary blood vessels of the leg so that fluid escapes through them into the surrounding tissues. Clots form in many of the small blood vessels under the skin, interfering with the blood supply of the superficial tissues and nerves.

The pain in the early or inflammatory phase is due to a lack of oxygen in the superficial tissues and nerve endings. Pain from this cause can be controlled by cooling the legs, as reducing the temperature of the part lowers cellular metabolism and makes the lessened demand for oxygen commensurate with the limited supply which can be furnished through the thrombosed superficial blood vessels. In the more severe cases aching pain and rigidity may persist long after the period of inflammation has subsided. Microscopic examination of biopsies from skin, subcutaneous tissue, and superficial muscle has shown that the rigidity and pain are due to an increase in interstitial connective tissue embedding the blood vessels, muscle fibers, and nerves.

When a person with immersion foot is rescued, the feet are discolored, blistered, swollen, and insensitive. When warmed, they become even more swollen, feverishly hot, and very painful.

After a period of 7 to 14 days the inflammation subsides but pain may persist for several months until the injured nerves have been fully repaired. Barring infection from the rupture of blisters and the entrance of virulent bacteria, the outlook is excellent.

Naval personnel, who may be exposed after shipwreck, should be taught that feet can be protected against cold and wet by avoiding tight shoes, greasing the skin, wearing woolen socks, or wrapping the feet loosely in odd bits of cloth. Elevation of the legs and exercising the toes is also helpful. However, under conditions of extreme subzero weather, where freezing of the feet would seem inevitable, the formation of ice-crystals and massive gangrene can actually be avoided by accepting the lesser evil of prolonged immersion.

When survivors are rescued with chilled, anesthetic, swollen, and blistered feet, they should be carried aboard and their skin protected against rupture of the blisters and pressure necrosis. Never rub the feet nor paint them with strong disinfectants. While the patient is being warmed, it is vitally important to keep the injured feet cool.

The blisters should be handled with aseptic precautions as would be a second-degree burn. Sulfonamides should be administered by mouth. A "booster" dose of tetanus toxide should be given. Elevating and cooling the legs will help drain the fluid and cause the blisters to shrink.

If, after rescue, the feet are warmed, the increased blood flow in the deeper vessels will cause increase in the discoloration, swelling of blisters, and severe pain.

Cooling of the feet is best accomplished by surrounding them with a dry bath towel and two to four ice bags, which are insulated from the surrounding air by a layer of cotton waste and a rubber sheet. Do not let the skin get wet. Maceration is harmful. Do not let the skin become too chilled. The temperature of the surface of the legs will tend to rise above that of the room and should be maintained (ideally) at about 70° F.

As the hyperemia subsides, the ice bags can be reduced in number and finally replaced by exposure to room air and a fan. After 10 days or 2 weeks the normal circulation is reestablished, blisters and swelling subside, and the skin peels with little or no necrosis. Patients should then be given a period of orthopedic foot exercises and allowed to get up.

After the treatment outlined, all but the most severe cases can return to duty in less than a month.

Warm-Seas Immersion Foot.—A condition similar to immersion foot has been found to occur in survivors adrift for long periods of time in warm seas.

The temperature of the sea even in the Tropics is considerably below that of the body, and it is possible that immersion over a long period of time at temperatures slightly lower than body temperature may have a result similar to immersion for a short period at temperatures greatly lower than that of the body.

In warm seas immersion foot the edema and nerve damage are said to be more marked, and the similarity of the clinical picture to beriberi led to the conclusion when it was first observed that this condition might be due to prolonged starvation, especially with respect to vitamin B. This view is probably incorrect. The vitamin-B requirements vary with the intake of carbohydrate food and a starving person requires very little vitamin B and

would not develop a deficiency of it before a number of weeks or months had passed.

Cramped posture with the lower extremities dependent may interfere with venous return and so slow the circulation in the legs that edema results and the tissues are damaged by lack of oxygen.

ACUTE ABDOMINAL SYMPTOMS

Acute Appendicitis.—When a hospital corpsman on duty on a ship that has no medical officer is confronted with a case of acute appendicitis, his judgment is put perhaps to its supreme test.

An attack of acute appendicitis may come on suddenly or may be preceded by mild premonitory gastro-intestinal symptoms such as loss of appetite, slight abdominal discomfort, constipation, or diarrhea. In a typical attack, the pain starts in the pit of the stomach and later localizes in the right lower part of the abdomen. The pain is usually dull and may be cramplike. Loss of appetite is the rule and frequently there is nausea. The temperature is often moderately elevated, but may be normal or subnormal. Usually there is a rapid pulse. If the inflamed appendix lies in its usual position, pressure with the fingers in the right lower quadrant of the abdomen will produce pain, and often the fingers will encounter a sensation of rigidity or spasm on gentle pressure over the abdominal muscles in this region. Sometimes upon sudden release of pressure applied elsewhere in the abdomen a twinge of pain is experienced in the region of the appendix. The white blood count is usually, but not always, elevated. Progressive elevation of the white blood count, especially when accompanied by a rise in the percentage of polymorphonuclear cells and by the appearance in the blood of increasing numbers of polymorphonuclear cells with nonsegmented nuclei, is a valuable danger signal.

In acute appendicitis the appendix tends to become full of pus, and the danger lies in its rupture with resulting peritonitis. In many cases the inflammation subsides spontaneously without rupture, whereas in others rupture may occur within a few hours. When peritonitis has supervened, the patient usually appears very ill and shows signs of shock with rapid pulse, rapid sighing respiration, and pale, moist skin. The temperature may be high or, as part of the picture of shock, low. The area of tenderness and muscle rigidity spreads to involve the whole abdomen, which may feel "boardlike."

The statement "Never give a cathartic to a patient suspected of having acute appendicitis" is often made but wiser advice perhaps would be: *Never give a cathartic to any patient who has any acute abdominal symptoms.*

It is generally-accepted principle in medicine that when a diagnosis of acute appendicitis is established and there are available a competent surgeon and adequate facilities for surgery, immediate operation represents the conservative and statistically safe procedure, while failure to operate may involve serious hazards for the patient.

Although appendectomies apparently successfully performed by pharmacist's mates on independent duty who had had hospital operating-room experience have been reported, it is the rare man not trained in surgery whose chances of proper diagnosis and successful operation are at all good.

The dangers of such surgical work must be weighed against the dangers of expectant, palliative, nonoperative treatment of acute appendicitis, but because war conditions may create situations in which hospital corpsmen should have discretion, orders discouraging such surgery by them have not been issued.

However, notoriety, commendation, or public acclaim should not encourage hospital corpsmen to engage in rash surgical adventures.

Treatment.

1. If it is in any way practicable, put the patient in the hands of a medical officer quickly.

2. Keep the patient in bed.

3. If a medical officer will be available within a few hours, give the patient no opiates.

4. If no medical officer will be available, give 0.01 to 0.15 Gm. (⅙ to ¼ grain) of morphine by hypodermic every 4 hours.

5. Give sulfadiazine, 4 Gm. (or 60 grains), by mouth as an initial dose and then 1 Gm. (or 15 grains) every 4 hours. Tissue hydration and an adequate flow of urine are essential when the sulfonamides are being administered. If the administration of intravenous or subcutaneous fluids is not feasible, water must be given by mouth. Water given by mouth stimulates peristalsis. This undesirable effect can be greatly lessened, however, by administering small amounts frequently and using cool water. If the patient is vomiting and sodium sulfadiazine is available, it may be given intravenously in 100 to 200 cc. of distilled water, or physiological saline or 5 per cent dextrose solution, the dosage used being the same.

6. Give nothing by mouth, except as mentioned before.

7. Give fluids intravenously or subcutaneously as required, using physiological saline or 5 per cent dextrose solution. If there is much vomiting, use of the former should be emphasized.

8. Place a hot water bottle (half filled) over the right lower quadrant of the abdomen.

9. If peritonitis develops and a medical officer is not available a nasal gastroduodenal catheter (Levin tube) should be passed intranasally into the duodenum, if possible, and connected with a suction apparatus of the Wangensteen type. This method of treatment may be the means of saving a patient's life, and all hospital corpsmen on duty independent of a medical officer should therefore be familiar with it. (See fig. 4).

Peptic Ulcer.—The term "peptic ulcer" is used to describe an ulcer of the stomach or duodenum. Gastric ulcers are rare in young men. The frequency with which duodenal ulcers occur in men of military age makes an understanding of their diagnosis and treatment important.

An ulcer of the duodenum starts as a small erosion of the duodenal wall. Its development is favored by the action of the gastric juices as they pass out into the duodenum from the stomach. As the ulcer erodes the wall, a crater is formed in the center, which may acquire considerable depth. The crater may deepen until perforation of the wall takes place or it may heal with the formation of scar tissue. Repeated episodes of activity in an ulcer tend to promote the formation of considerable scar tissue which contracts and produces deformity of the wall.

It is not known why certain individuals are more likely than others to develop peptic ulcers. These ulcers most frequently occur in thin, wiry individuals with narrow costal angles who have the masculine rather than the feminine type of body build. People with ulcers also tend to belong to certain psychological types.

It has been often demonstrated that emotions affect the motor and secretory activity of the stomach. It is probable that prolonged emotional tension, as caused by suppressed fear, or anger, or a sense of frustration, may produce

enough disturbance of the physiology of the stomach and duodenum in a susceptible person to result in the formation of an ulcer.

The uncomplicated duodenal ulcer is usually associated with motor overactivity of the stomach, hypersecretion of mucus, pepsin, and hydrochloric acid, and rapid emptying. And conversely, all of the disturbances in physiology favor its development.

SYMPTOMS.—The patient with an uncomplicated duodenal ulcer usually presents a typical history. The symptoms frequently develop while under some emotional strain, as for example, adjustment to military life. The patient usually describes a dull, gnawing pain the center of the upper part of the abdomen (just below the xiphoid process) which is relieved by the ingestion of food and of alkalies and tends to recur from 2 to 4 hours after the meal. Usually the appetite is preserved, there is no vomiting, and there is no disturbance of the bowels. Frequently there is a history of a similar attack in the past. Examination of the abdomen reveals nothing abnormal except possibly slight tenderness under the xiphoid. However, a gastrointestinal X-ray examination with barium, when available, shows some deformity of the duodenum and possibly the knob-like shadow of a crater.

COMPLICATIONS.—There are three important complications of a duodenal ulcer. In order of frequency they are: Hemorrhage, obstruction, and perforation.

Hemorrhage may occur suddenly and make itself immediately evident with the vomiting of blood. More often it occurs insidiously, the first symptom being a sense of weakness. This is then followed by the passage of stools that are so black that they are described as "tarry". A patient who has bled from an ulcer is pale, and if the hemorrhage has been of some magnitude, will have rapid pulse, low blood pressure, sweating, and other signs of impending shock.

Obstruction.—Two factors tend to promote obstruction, contraction of the lumen of the duodenum by scar tissue, and edema (swelling) of the wall secondary to the inflammatory reaction surrounding an active ulcer.

When obstruction develops, the symptomatology takes on a new pattern. The appetite is lost, the pain may become more severe and cramp-like and tends to be aggravated by food, vomiting occurs frequently, and often the vomitus contains food eaten some time before.

Perforation.—There may be a premonitory aggravation of the pain, which will assume a steadier character, or the symptoms may occur without warning. The patient is suddenly seized with pain in the upper part of the abdomen, of great severity and usually of a burning character. The painful area spreads gradually downward. Vomiting may occur. The patient usually is pale, sweaty, with subnormal temperature at first and rapid pulse, lies still, and there may be a considerable degree of shock. There is marked tenderness in the upper part of the abdomen, spreading downward, and palpation of the abdomen reveals a board-like resistance which gradually involves the whole abdomen.

In talking to a patient with any of these three complications, a history of previous experience with the characteristic ulcer pain can often be obtained.

TREATMENT.—*A. Uncomplicated duodenal ulcer.*

1. Do whatever is possible to relieve nervous tension. It is sometimes wise to administer a mild sedative such as phenobarbital (¼ to ½ grain, t. i. d., p. c.).
2. Give one-half to one glass of milk between meals, at bedtime, and if the patient wakes at night.
3. Give small meals composed of nonirritating foods. (Foods that are coarse, raw, highly seasoned, uncooked, very hot, very cold, or greasy,

and alcohol are not to be allowed. Fruit juices in moderate amounts should be allowed and salt should not be restricted.)

4. Instruct the patient to chew thoroughly and eat slowly.
5. If abdominal discomfort persists, an alkali such as calcium carbonate may be given in doses of 30 grains one-half to one hour after feedings.
6. As soon as practicable, transfer the patient to a naval hospital for diagnostic study.

B. Hemorrhage.

1. Keep the patient in bed with the foot of the bed slightly elevated.
2. Treat for impending shock: (*a*) Give morphine, ¼ grain, and subsequent smaller doses as indicated; and (*b*) transfuse with whole blood (plasma if whole blood is not available) as indicated by condition of the patient, pallor, blood pressure, pulse, etc.
3. Allow sips of saline solution at room temperature.
4. Give from the start 2 ounces of milk every hour by day and every 2 hours by night.
5. Beginning on second day (even if hemorrhage continues) replace occasional milk feedings with simple soft foods such as soft-boiled eggs, soft cereals, melba toast, scraped meat, strained fruits and vegetables, mashed potatoes, etc.
6. Do not give an enema or a cathartic.
7. Place a half-filled hot water bottle (with air expelled from it) on the abdomen.
8. Avoid frequent examinations of the abdomen.
9. When the return of the stool to a normal color gives evidence that bleeding has stopped, feed as for an uncomplicated duodenal ulcer.
10. Place under care of a medical officer as soon as practicable.

C. Obstruction.

1. Keep patient in bed.
2. Place a half-filled hot water bag on the abdomen.
3. Allow saline solution, milk, cereal gruel, and fruit juices as tolerated.
4. At bedtime lavage the stomach through a Levin tube with warm saline solution and let a little remain.
5. Measure the intake and output (including stomach contents removed at lavage and vomited).
6. Supplement fluids given by mouth with intravenous fluids in amounts sufficient to provide an excess of total intake over total output of at least 2 liters and to produce at least 1 liter of urine a day. Dextrose and saline solution may be used, but enough saline solution should be be given so that the patient retains at least 10 Gm. of salt a day.
7. As soon as practicable, put the patient under the care of a medical officer.

D. Perforation.

The accepted management of a perforated ulcer includes immediate exploratory operation and suture of the perforation. Therefore, every effort should be made to bring the patient immediately, if possible, under the care of a medical officer.

When a medical officer is not available, as much of the program following should be carried out as is feasible with the existing facilities.

1. Keep the patient in bed with the head of the bed slightly raised.
2. Give morphine, ¼ grain, at once to relieve pain and subsequent smaller doses at 4-hour intervals as indicated.
3. Place a half-filled hot water bag on the abdomen.

4. Give sodium sulfadiazine intravenously, 4 Gm. (or 60 grains), at once and then 1 Gm. (or 15 grains) every 4 hours, day and night.
5. Allow no fluids or food by mouth.
6. Pass a Levin tube into the stomach and connect it with continuous Wangensteen suction. (See fig. 4.)

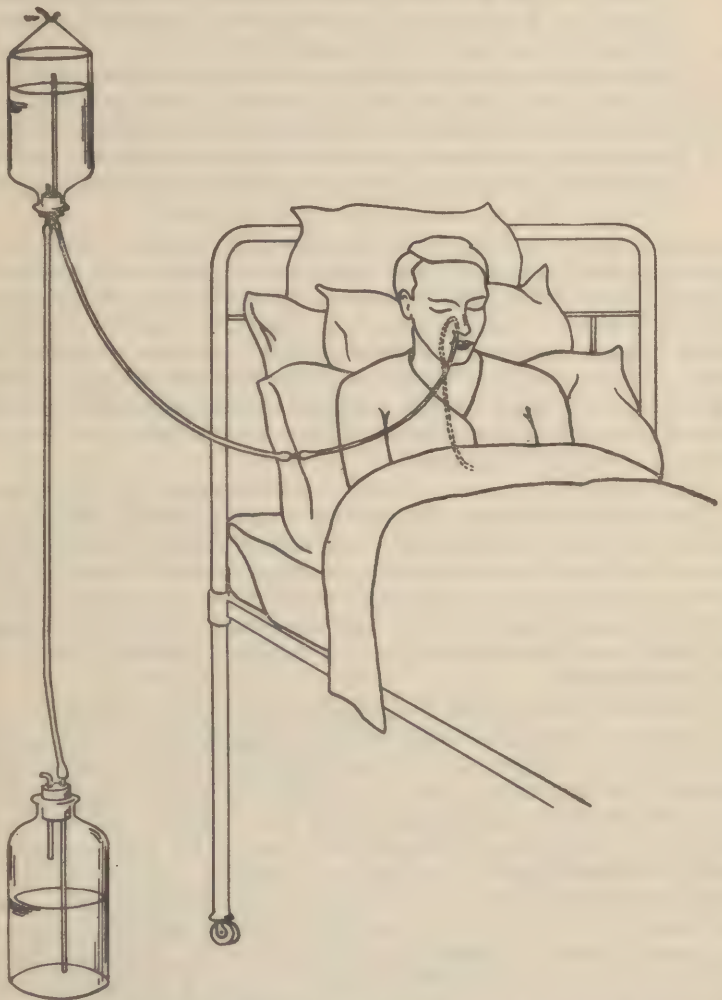

FIGURE 4.—A simple method of providing continuous gastric or duodenal suction with the Levin tube.

7. Treat shock (and hemorrhage if present) with whole blood or plasma.
8. Supplement fluids given by mouth with intravenous fluids in amounts sufficient to provide an excess of total intake over total output of at least 2 liters and to produce at least 1 liter of urine a day. Dextrose and saline solution may be used, but enough saline solution should be given so that the patient retains at least 10 Gm. of salt a day.
9. Place the patient under the care of a medical officer as soon as possible.

SOME COMMON EMERGENCY SYMPTOMS

Treatment of Diarrheal Diseases.—When a patient complains of having diarrhea, the following conditions ought to be considered as possible causes:

1. Food poisoning: (*a*) Bacterial, as *Salmonella* infections; (*b*) bacterial toxins, as *Cl. botulinus*, staphylococcus; (*c*) plant toxins, as in mushroom poisoning; or (*d*) other toxic substances, as bichloride of mercury, sodium fluoride (roach poison), etc.
2. Bacterial and protozoal diseases such as: (*a*) Dysentery (bacillary, as Flexner, Shiga, etc., amoebic, or caused by other protozoa); (*b*) typhoid and paratyphoid fevers; (*c*) cholera; and (*d*) trichinosis.
3. Miscellaneous diarrheal diseases such as: (*a*) Diarrhea complicating respiratory disease; (*b*) diarrhea caused by food sensitivity, nervousness, etc; and (*c*) heat cramps (stoker's cramps).

A brief discussion of these conditions, including primarily those for which recent improvements and advances in treatment have been made, follows.

1. FOOD POISONING.—This subject is very fully developed on page 377 of the *Handbook of the Hospital Corps, U. S. Navy.* Certain advances have been made which deserve mention. The general name "ptomaine poisoning" used to be given to this group of diseases, but it is now clear that the majority of cases of food poisoning are due to bacteria actually growing in the food or to poisonous products of the bacteria themselves, and not to food-decomposition products, or "ptomaines", as was formerly believed.

(*a*) SALMONELLA INFECTIONS.—The onset is usually 12 to 24 hours after eating the contaminated food, although the interval may be somewhat longer or shorter. The onset is rather sudden with nausea, vomiting, abdominal cramps, and diarrhea. There may be dizziness, headache, fever, prostration, and perhaps even shock (circulatory failure). Thirst is often marked. Stools tend to be foul, yellow-green or brown, and sometimes contain blood flecks and mucus. The illness generally lasts 2 to 3 days and recovery is slow (1 to 2 weeks) but complete.

Cause.—The bacteria (*Salmonella*) which give rise to this condition are related to the organisms which cause paratyphoid fever. The members of this group are very widespread in nature and more than a hundred different strains have been isolated thus far. It is interesting that the strains which give rise to food infection in man are the cause of a disease in animals quite like typhoid fever. As the *Salmonella* are often present in the flesh of these infected animals it is readily apparent why meat, meat products, and milk are frequently contaminated by *Salmonella.* This disease can be transmitted also from man to man because the bacteria which grow in the intestine pass out in the feces and may be spread by fecal contamination of food and water. Failure on the part of a food handler to wash the hands after going to stool is an important factor in the spread of this infection. (Bacteria in the human intestine cause tremendous irritation and swelling of the mucosa, and produce the symptoms described.)

Treatment.—There is no specific treatment. *No purgatives should be used.* The patient should be put to bed, made comfortable and warm. Fluid balance should receive careful attention because of loss of water and salt through vomiting and diarrhea. Often as much as 4 to 5 quarts of sugar and salt solution should be given (4 tablespoonfuls of sugar and 2 teaspoonfuls of salt to a quart of water). Solid food and cold drinks should be avoided while the gastrointestinal tract is upset. Codeine sulfate (30 to 60 mgm. or ½ to 1 grain) by mouth, or even morphine sulfate (8 to 15 mgm. or ⅛ to ¼ grain) by hypo may

be necessary owing to the pain or shock. Bismuth subcarbonate (0.5 Gm. or 7½ grains) every 2 to 4 hours is of help in controlling the diarrhea. Occasionally camphorated tincture of opium (paregoric) ½ to 1 teaspoonful, or 2 to 4 cc., every 2 to 4 hours to a total of 6 doses a day, may be of use in controlling the abdominal cramps. A hot-water bag applied to the abdomen is helpful. After the acute phase the patient is gradually allowed up and at the same time is gradually returned to a full diet starting with foods low in residue. Occasionally it is necessary to treat dehydration by the use of intravenous saline solution. Throughout the illness it is well to use the same precautions against spread to others that would be used in a case of bacillary dysentery (see under that topic for information as to isolation of the patient, care of urine and stools, care of mess gear, protection of attendants from infection, etc.), because the causative bacteria are being thrown off by the patient constantly in the urine and stools.

(*b*) Staphylococcal Intoxications.—These are probably the commonest food poisonings encountered. They begin very abruptly and very soon after the toxic food is eaten (½ to 6 hours). (The time relationship is often a point of value in differentiating this condition from *Salmonella* food infections.) These intoxications are characterized by nausea, abdominal cramps, frequent vomiting, and headache. Diarrhea may begin at once or after a few hours and generally consists of 1 to 10 watery stools. The patient may complain of cramps in the legs and occasionally dehydration may be so severe that the patient may go into shock. The total acute illness generally lasts no longer than 10 to 12 hours, but several days are required for complete recovery.

Cause.—Staphylococci are usually introduced into food by a food handler. The source is usually an infection of the hand or a pustule on the face with which the hand has come in contact. They grow in the food and produce a true toxin which causes the gastrointestinal symptoms. Ham is notorious for acting as the vehicle for staphylococcal intoxication. Cooking ham will kill staphylococci but it will not destroy the toxin that has already been formed. The toxin is very heat-resistant; it can withstand exposure to boiling water for 30 minutes. It has also been shown that salt as used in the preservation of meat may control perfectly the growth of *Salmonella* bacilli and yet utterly fail in controlling the growth of staphylococci. Cream-filled pastries are another well-known agent of transmission for this intoxication. Here the cream filling acts as a fine medium for bacterial growth when it is accidentally contaminated by the food handler. These types of food should not be allowed to remain very long in a warm room and should never be used after they have been allowed to remain overnight unless refrigeration has been entirely satisfactory. The only way to avoid staphylococcus-food infections is to provide continuous refrigeration of all foods which support the growth of the staphylococcus.

The foregoing shows why it is necessary frequently to inspect food handlers of all kinds in order to prevent anyone with boils or skin infections, or diarrhea, from coming into contact with food.

Treatment.—Again, treatment is symptomatic. The patient should be put to bed and kept warm, for he may collapse if he continues to be up and about. If dehydration and shock are present, they should be treated with saline solution, etc. *No cathartics are to be used.* Fluids (as discussed under *Salmonella* infections) should be given as soon as the patient is able to retain them. Codeine or morphine may be necessary to control pain. Within a day or two the patient should be back on a full diet.

(*c*) BOTULISM.—This poisoning by *Clostridium botulinus* is adequately explained on page 379, *Handbook of the Hospital Corps.* Usually only a very few cases of this disease have associated diarrhea. When available, the antitoxin must be used early to be of value in treatment.

(*d*) MUSHROOM POISONING is characterized by rapid onset (15 minutes to 6 hours), excessive salivation and perspiration, flow of tears, nausea, retching, abdominal pain, vomiting, profuse watery diarrhea, coma, and oftentimes by death. The cause is an alkaloid in the mushroom itself. *Treatment* consists of symptomatic and supportive measures and stomach lavage.

(*e*) OTHER POISONS (TOXIC SUBSTANCES).—The symptoms and treatment of bichloride-of-mercury poisoning are fully discussed on page 266, *Handbook of the Hospital Corps.*

2. BACTERIAL AND PROTOZOAL DISEASES.—Some reference to the treatment of several of these diseases has been made in the outline of instructions relative to the use of sulfonamides in the absence of medical officers (see p. A44 of this addendum), and on page 339, *Handbook of the Hospital Corps.* It seems in order to expand that discussion here.

(*a*) BACILLARY DYSENTERY.—The onset is usually quite sudden, but generally occurs from 2 to 7 days after ingesting the contaminated food or water. Fever (100° to 104° F.) and abdominal cramps are present. Watery stools, which contain very little fecal matter, soon characteristically contain mucus and blood. Each of these stools is immediately preceded by a painful desire to defecate (tenesmus); there may be as many as 20 to 50 stools in a 24-hour period. Marked dehydration may occur and the patient may become extremely ill, perhaps even go into profound circulatory collapse (shock).

Cause.—The usual causative organism is one of the dysentery bacilli, as the Flexner dysentery bacillus, Shiga dysentery bacillus, Sonne baccillus, etc. These bacteria have no special geographical preference, although the Flexner type is somewhat more common in the United States, while the Shiga type is more prevalent in the Orient. The organisms grow primarily in the large intestine and cause shallow ulcers in the bowel mucosa. The Shiga bacilli, in addition to this local bowel action, also produce a toxin which is absorbed into the blood stream and may produce central-nervous-system symptoms such as respiratory embarrassment, muscular twitchings, and even nerve paralysis. Like the causative bacteria of the other intestinal diseases, all of these organisms may be transmitted through contaminated material from carriers or actual cases to other humans, either directly by humans, by flies, or by fecal contamination of food and water, etc. From an appreciation of these facts it becomes clear why isolation precautions must be used, not only with respect to the patient, but also with respect to the patient's excreta, linen, dishes, etc.

Treatment.—Bed rest with good intestinal disease isolation technique is important. (This latter point is discussed in the section on "Nursing Care of Communicable Diseases," page 335, *Handbook of the Hospital Corps*, and includes isolation of the patient, use of gowns and cleansing of hands by attendants, care of linens, utensils, dishes and dejecta, precautions regarding visitors, and similar topics.) Diet will be liquid or soft low-residue until the patient is convalescing, and then will be gradually increased to full ration. Fluids (3,000 cc. or more) must be given in order to maintain a urine output of 1,200 to 1,500 cc. daily. In some severe cases, especially when the patient is badly dehydrated and in shock, it may be necessary to give 5 percent dextrose in normal saline solution intravenously. At times it will be advisable to use paregoric, codeine,

or even morphine in order to control abdominal pain (see under *Salmonella* infections).

Sulfonamides are of articular value in the treatment of bacillary dysentery. In acute bacillary dysentery *sulfadiazine* appears to be the drug of choice, with sulfathiazole second. The dose is 2.0 Gm. (or 30 grains) initially, followed by 1.0 Gm. (or 15 grains) every 6 hours until symptoms have subsided. (1 to 2 Gm. (or 15 to 30 grains) of sodium bicarbonate should be given with each does of sulfadiazine.) The sulfonamide may be discontinued after the patient has been well for 2 days. It is important that chronic cases, and cases which do not respond to sulfadiazine or sulfathiazole within 5 to 7 days be got under the care of a medical officer as soon as possible. Whenever any of the sulfonamides are administered, it is important to maintain a daily urine output of at least 1,200 cc., and upon any evidence of drug toxicity or appearance of a urinary-tract complication, the medication must be stopped immediately.

An antitoxin has been developed for Shiga dysentery but is of value only when that organism has been definitely identified, and when administration of the antitoxin may be begun early in the disease. Forty to 80 cc. intravenously twice a day in 500 cc. of physiological saline solution is given until the temperature falls to normal.

(*a*) (*cont.*) AMOEBIC DYSENTERY.—In contradistinction to the diseases which have already been discussed, amoebic dysentery generally has an insidious onset. This has given rise to its popular name of "walking dysentery." There is some abdominal discomfort, and then gradually increasing diarrhea. This development of symptoms may even occur a few weeks or many months after the original infectional ingestion. Generally there are some loss of weight, fatigue, and weakness. Fever is usually mild. Grossly the stools in amoebic dysentery have a fetid odor and show an admixture of mucus, while in bacillary dysentery they tend to be thin and albuminous in odor. Microscopically the distinction is quite clear: Mucus with few blood cells being characteristic of amoebic dysentery, while large numbers of pus cells with red blood cells are seen in bacillary dysentery.

Cause.—The *Endamoeba histolytica* is the cause of this type of dysentery, and it exists either as an active amoeba (when living conditions are favorable) or a cyst (when conditions for survival are unfavorable). The infective agent is ingested with contaminated food and water. The cysts pass through the stomach juices unharmed, lose their cyst walls in the small intestine and develop into adult amoebae there and in the lower bowel. The adult forms find the large intestine more favorable to their growth, dissolve their way through the mucosa and come to lie in the bowel wall itself. This process gives rise to the deep, ragged ulcers in the large intestine which are so characteristic of amoebic dysentery, and which, in turn, give rise to the symptoms. If the dissolving process is more extensive, and it frequently is, the protozoa may extend into the neighboring tissues and even into the portal vein, from whence they are carried to the liver, amoebic abscesses occasionally resulting. Abscesses may rarely occur at other sites, notably in the lung or brain. The untreated disease is a long-drawn-out affair, characterized by recurrences, and many patients, unless satisfactorily treated, become carriers. These carriers, as well as active cases, commonly transmit the disease by contaminating water and food, either directly or by pollution of inadequately protected supplies. (Ordinary chlorination of water does not provide satisfactory protection from *E. histolytica* cysts.)

Treatment.—For amoebic dysentery there are general measures to be considered in the treatment. Diet should be full and augmented by vitamins, if

the patient's general condition is poor. Fluid balance must be maintained (as described under Bacillary Dysentery). Purgatives are of no value. Attention should be given to the disposal of excreta, care of linen and dishes, etc., as previously outlined.

It is fortunate that there are drugs which are specific therapy for this disease. Emetine hydrochloride is given subcutaneously, 0.065 Gm. (or 1 grain) once daily for 5 days. The patient must be kept absolutely in bed during the administration of emetine. On the third day of emitine therapy carbarsone is begun, and 0.26 Gm. (or 4 grains) is given by mouth 3 times a day for 7 days. A rest period with no medication for 7 days follows. Then vioform, 0.26 Gm. (or 4 grains), is given by mouth 3 times a day for 7 days. Another rest period of 7 days ensues. A repeat course of carbarsone, 0.26 Gm. (or 4 grains), is given by mouth 3 times a day for 7 days. (When vioform is not available, chiniofon (Yatren) 1.0 Gm. (or 15 grains) by mouth 3 times a day after meals, or diodoquin, 0.65 Gm. (or 10 grains) by mouth three times a day for 7 days may be used.) The patient should be put under the care of a medical officer as soon as possible after the diagnosis is made.

(*b*) TYPHOID AND PARATYPHOID FEVER.—Diarrhea is a rather infrequent symptom of these diseases. For this reason, because of the lack of specific therapy and because of the almost total absence of these diseases in naval life by virtue of the immunization program, no dicussion of treatment will be set down here.

(*c*) CHOLERA.—Although this disease is constantly present in maritime Asia, it has not been observed in the United States for many years. A number of great epidemics have, however, spread from Asia throughout the world during the past century, generally with devastating effect on the populace. An incubation period of from 1 to 5 days ensues after the ingestion of food or drink contaminated by infected feces. The patient develops sudden, profuse diarrhea and vomiting. Owing to the fact that both vomitus and stools contain large quantities of sloughed mucous membrane and water, the typical ejecta of cholera have been called "rice water." The diarrhea is said to be relatively painless, but, after the disease has been in progress a short time, agonizing cramps may set in, especially in the legs and abdomen. At first there is high fever but, growing progressively more ill and more exhausted, the patient later becomes cold and has a subnormal temperature. Large amounts of fluid are lost from the body tissues so that dehydration, prostration, and shock develop with great rapidity. Obviously, convalescence will be slow and protracted, if the individual survives.

Cause.—The *Vibrio comma*, so called due to its slightly bent outline, is the causative agent of cholera. The organisms grow in contaminated food and water and are transmitted as other food- and water-borne diseases. The bacteria multiply in the intestine, especially in the small bowel and cause irritation and desquamation of the mucosa. Although some authorities have believed that *V. comma* produces a toxin, it seems evident that in the majority of cases the signs and symptoms are referable directly to the gastrointestinal tract infection and the resultant severe dehydration. Prevention is largely by the avoidance of pollution of food and water supplies, by careful attention to the care of the patient and the excreta, by extreme care in avoiding the use of contaminated food and water supplies, and by immunization (vaccination) of personnel who are going into an area where cholera is present.

Treatment.—Bed rest, warmth, and constant care are essential. Sulfonamides (as indicated under Bacillary Dysentery) may be given. There is little evidence, however, that these drugs will be of any material benefit. Diet will be very light (as tolerated).

Fluid is the key to adequate treatment of cholera. The patient should be given fluids at least every hour by mouth, and permitted to take as much as desired (unless drinking these fluids seems to cause nausea or vomiting). Water, 1 per cent salty broth (bouillon), 5 per cent dextrose in normal saline solution (4 tablespoonfuls of sugar or dextrose and 2 teaspoonfuls of salt to the quart of water) or Lactate-Ringer's (Hartmann's) solution are the most acceptable fluids. Intravenous or subcutaneous infusions (normal saline solution, 5 per cent dextrose in normal saline solution, or Lactate-Ringer's solution (Hartmann's)) are life-saving. Moderately severe cases will require 4 liters daily, and cases of greater severity will need more. The state of the skin, the tongue, the eyeballs, the urinary output, the blood pressure, and the thirst will be satisfactory guides for determining the amounts of fluids required. After a sufficient degree of hydration has been attained, judicious use of plasma or whole blood often may be indicated.

(*d*) TRICHINOSIS.—This is primarily a disease which results from eating pork containing the *Trichinella spiralis* which has been improperly and incompletely cooked. A week or so after ingestion of the pork, the patient has a mild or moderately severe gastrointestinal upset, often with cramps and diarrhea. This stage coincides with the development of the *trichinae* in the small intestine (they grow from the encysted forms in the pork) and the irritation which results from their invasion of the bowel wall. They are then carried by the blood stream to the muscles. At this stage muscle tenderness and fever are usually present. Characteristically these cases exhibit a high eosinophile count in the blood smear. There is no treatment, other than symptomatic.

3. MISCELLANEOUS DIARRHEAL DISEASES.

(*a*) "INTESTINAL FLU" is a poor title for the gastrointestinal upsets which frequently accompany colds and other upper respiratory tract infections. When diarrhea does occur, liquid or bland, soft diets should be given. Bismuth subcarbonate (1.0 Gm. or 15 grains) 3 or 4 times a day, or camphorated tincture of opium (paregoric), ½ teaspoonful (or 2 cc.) every 2 hours for 6 doses, may be given if necessary. Application of a hot water bottle to the abdomen is very soothing.

(*b*) Occasionally an apparent digestive upset may be traced to food sensitivity, or to upset emotional balance ("nervousness"). In either case, the diet should be made bland for a few days until equilibrium is reestablished. Investigation should be made to determine the offending food or circumstance so that it may be removed from the individual's environment. Not infrequently phenobarbital, (0.03 Gm. or ½ grain) one to three times a day, is useful in helping to control the symptoms in these cases.

(*c*) HEAT CRAMPS (STOKER'S CRAMPS) are described as sometimes being accompanied by severe abdominal cramps and watery diarrhea. Ordinarily this condition is characterized by muscle cramps in the extremities; it follows excessive sweating and failure to increase the salt intake during those sweating periods.

Treatment consists of taking a quart or more normal saline solution by mouth, if possible, or by vein, if necessary.

It must be remembered that the first symptom of appendicitis may be diarrhea.

SUMMARY.—Any limited discussion of a large field is necessarily incomplete. Certain factors and advances in treatment that stand out as important in the handling of diarrheal diseases follow.

(*a*) A diagnosis should be made if possible before treatment, other than symptomatic, is started.

(*b*) The patient should be removed from the causative agent insofar as possible.

(*c*) The patient's excreta, linen, dishes, etc., should be treated as indicated before disposal, in order to prevent spread of certain of the diseases.

(*d*) Purges and cathartics have no place in the treatment of the diarrheas.

(*e*) Sulfonamides have been found to be of great value in bacillary dysentery.

(*f*) Emetine, carbarsone, and vioform (or chiniofon) should be used in amoebic dysentery.

(*g*) Antitoxin is available for botulism and for the Shiga type of bacillary dysentery.

(*h*) When diarrhea or vomiting is severe, dehydration and salt loss are the greatest danger to life, and fluid and salt replacement is essential.

BLAST INJURY

The condition termed *blast injury* results from exposure to the detonation of large quantities of high explosives such as depth charges, aerial bombs, powder magazines, etc., and is, so far as is known, confined to the air-containing organs of the body, the lungs and the gastrointestinal tract. The condition may occur in the air but generally occurs in water.

Explosions in *air* do not commonly result in serious "blast injury," and experience has shown that the chief hazards of such explosions are burns and single or multiple wounds produced by flying shrapnel, or fractures and contusions occurring when men are thrown against bulkheads, lockers, guns, etc. Treatment of these injuries then takes precedence over the diagnosis and treatment of such damage as may have occurred purely from air blast. True blast injury has occurred in closed turrets or in other confined spaces within a ship, but such cases have fortunately been rare.

The power of an explosion is readily transmitted through *water* to a considerable distance, and consequently injuries from blasts taking place under water (depth-charges) are fairly common at the scene of engagements where a ship has been abandoned and persons are swimming or floating in the water near a sinking ship. In the case of underwater explosions, flash and shrapnel are absent, but serious injury to the lungs and gastrointestinal tract may result from the concussion alone.

Blast injury in water is caused by a wave of compression—the "concussion wave," or "shock front"—transmitted from the exploding charge through the water, and thence through the body of the swimmer. Tissues containing air or gas (lungs, intestine) are "shredded," just as is the surface of the water directly over an exploding depth-charge. This tearing of the tissue produces hemorrhage in the lungs which, if sufficiently severe, may lead to death from shock and asphyxia. In the intestine, hemorrhagic patches may be produced at the location of gas bubbles within the intestinal cavity. These small hemorrhages may not result in serious injury or may cause such damage to the intestinal wall that a perforation later results. With blasts of sufficient intensity, an immediate "blowout" of the intestine may occur.

Symptoms.

Blast injury may be suspected in personnel who have been in the neighborhood of violent explosions, particularly in those who have been floating in waters where depth-charges have been detonated. The symptoms of "blast lung" are frothy, bloody sputum, labored, noisy and painful breathing, with pallor and shock.

Intestinal injury is shown by abdominal pain and cramps, bloody diarrhea and a tender, board-like abdomen. The history will be that of having been in the water and feeling a powerful blow on the abdomen, followed shortly by cramps and often by loose bowel movements even while still in the water. In persons wearing life-jackets, abdominal injury may take place with no evidence of damage to the lungs, because the life-jacket cushions the blast and protects the chest.

Treatment.

"Blast lung" is treated in somewhat the same manner as pneumonia. Rest in bed is essential and where blast injury is suspected, the patient should be moved very carefully, as rough handling may increase internal bleeding. For the same reason artificial respiration should not be used unless breathing has stopped entirely. Giving the patient oxygen, by mask, has been found very beneficial and 0.016 Gm. (or ¼ grain) of morphine may be given to relieve restlessness. Sulfonamides orally are recommended as prophylaxis against pulmonary infection. Plasma or whole blood should be given for shock, but overenthusiastic intravenous therapy may aggravate the tendency to develop edema of the lungs.

The skill of a medical officer is necessary for the definitive treatment of abdominal blast injury. Patients with this condition are carefully watched for symptoms of a perforated intestine when, of course, surgery must be performed if the patient's life is to be saved. When a medical officer is not available, the patient may be given 0.016 Gm. (or ¼ grain) of morphine to allay pain and restlessness and sulfonamides may be administered to combat peritonitis, in case an intestinal perforation is present. Enemas or fluids by mouth should be avoided when perforation is suspected. Whole blood or plasma may be given the patient in shock. The control of shock is particularly important in these cases, for if perforation is found to be present, the patient will be in better condition for operation if shock is controlled.

MATERIA MEDICA AND THERAPEUTICS

THE SULFONAMIDES.

History and Chemistry of the Sulfonamides.

HISTORICAL DEVELOPMENT.—The synthetic-dye industry has given the world many chemotherapeutic agents but probably none more valuable than the compounds called the "sulfonamides." The story of the development of these compounds as chemotherapeutic agents is intimately connected with the synthetic-dye industry.

Synthetic or artificial dyes, also known as coal-tar dyes, aniline dyes, etc., were first produced in England in 1856 and their manufacture has since become an important industry. Synthetic dyes, like those of natural origin, are complex compounds of carbon in association with other elements, especially hydrogen, nitrogen, oxygen, or sulfur, and they belong, chemically, to the class of organic compounds termed the aromatic hydrocarbons. (See pp. 714 and 722 of the *Handbook of the Hospital Corps, U. S. Navy.*)

As in organic aromatic compounds in general, synthetic dyes have their constituent carbon atoms arranged in the closed-chain or benzene-ring form and they may be regarded as derived from closed-chain hydrocarbons by the replacement of certain of the hydrogen atoms by atomic groups of other elements. Nearly all synthetic dyes are derived from some one of the five hydrocarbons termed benzene, toluene, xylene, naphthalene, and anthracene, the most convenient source of which is coal-tar. From these hydrocarbons the various dyes are built up in successive stages, the first of which is the conversion of the hydrocarbons into what are called intermediate products.

These intermediate products are formed when one or more of the hydrogen atoms attached to the carbon nucleus are replaced by atomic groups such as the amido group, NH_2, the hydroxyl group, OH, the sulfonic group, SO_3H, etc. In most cases the intermediate products are colorless bodies like the hydrocarbons from which they are derived but they become dyes when a greater complexity of their molecular structure is obtained through further chemical treatment. To effect this change in molecular structure additional substituent groups may be introduced or the molecules of two or more intermediate compounds may be linked together into a larger molecule.

The manufacturers of synthetic dyes at an early date placed dependence upon scientific research for their manufacture and development and established extensive laboratories for that purpose. Out of the manufacture of synthetic dyes has grown a large industry in such products as medicinals, flavors and perfume materials, rubber chemicals, resins, and miscellaneous coal-tar chemicals. Another product closely related to the dye industry is the war gases.

Among the many medicinal products is the group of compounds known as the "sulfonamides" and commonly called "the sulfa drugs." One of the first of these compounds to appear was para-amino-benzene-sulfonamide which was synthesized in Germany in 1908. At that time this substance, which today is known as sulfanilamide, was considered only as a dye and investigations into its uses appear to have been confined almost solely to its use in the dye industry.

It was not until 1935 that it became recognized as a chemotherapeutic agent. Between 1908 and 1935 it was noted at various times that some of the dyes containing the sulfonamide group were bactericidal *in vitro*, i. e., in a glass container as distinguished from in a living organism, and these observations no doubt led to the investigations that ultimately proved the value of these compounds as chemotherapeutic agents.

In organic chemistry *azo* is a combining form that denotes the presence in a compound of a group of two nitrogen atoms attached on either side to carbon, as in azobenzene, in azodicarboxylic acid, and, uncommonly, to some other element, as in azodisulfonic acid. Aromatic compounds containing this group of nitrogen atoms are called azo-compounds and are the basis of numerous dyes known as azo-dyes. One of these azo-dyes is of particular interest, for it was the first one whose use as a chemotherapeutic agent was reported.

In 1909 a German chemical company prepared azo-dyes with sulfonamide and substituted sulfonamide groups and it was found the azo-sulfonamide compounds were excellent dyes for textiles, but it is not known if any attempt was made to apply them to the control of bacterial infections. In 1914 it was noted the azo-dye chrysoidine (diamino-azobenzene-hydrochloride) was bactericidal *in vitro*. Subsequent to this observation phenyl-azo-diamino-pyridine hydrochloride (a product of an azo dye and having the trade name of pyridium) was synthesized and in 1926 was introduced as a urinary antiseptic. A number of azo-dyes were developed in 1919 and it was reported that many "were highly bactericidal *in vitro*".

The preparation of diamino-azo-benzene-sulfonamide, or chrysoidine sulfonamide (known later as Prontosil) was postulated in 1920 by a German chemical company in an English patent but it was not fully described in English patent literature until 1935. Prontosil is the proprietary name of a red azo dye.

During the time between the postulation of Prontosil and its actual synthesis chemists and biologists tested out the chemotherapeutic effects of numerous gold, antimony, and organic arsenical compounds and certain tin salts in experimental bacterial infections without obtaining suggestive results. Intensive chemical investigations upon the synthesis of azo-dyes containing sulfonamide and designed for use as chemotherapeutic agents in the control of bacterial infections, probably were not begun until sometime in 1930 after completion of the work that led to the synthesis of atabrine. (Atabrine (Quinacrine hydrochloride, U. S. P. XII) is the name of a proprietary preparation widely used as an antimalarial and derived from acridine, a hydrocarbon that in structure resembles anthracene (with which it occurs in coal tar) and is the parent substance in the synthesis of certain dyes and drugs.)

Before the synthesis of Prontosil it is known that at least one azo-dye containing sulfonamide had been found to be quite effective in the control of experimental streptococcal infections. When Prontosil was synthesized is uncertain, but a patent that covered the original Prontosil, as well as several other azo-dyes containing sulfonamide, was issued by the German patent office in December 1932. A few months later, in 1933, it was reported that this substance, under the name of streptozon, had been used in a case of septicemia resulting from a staphylococcal infection. Although other reports of its use in infections followed but little attention was paid to it until after February 1935, when the report of Gerhard Domagk, a German pathologist, on its use in bacterial infections was published in a German medical journal.

Domagk stated that, when given by mouth in small doses, Prontosil prevented the growth of otherwise fatal hemolytic streptococcal infections in mice, con-

trolled and cured chronic streptococcal infections in rabbits, and produced beneficial results in staphylococcal infections in rabbits, but was without effect in the treatment of certain pneumococcal and other experimental infections. He also stated Prontosil was without bactericidal effect *in vitro* and acted as a true chemotherapeutic agent only in the living animal.

The results of Domagk's investigations were corroborated by other workers and later in 1935 French investigators concluded that the azo linkage in the compound diamino-azobenzene-sulfonamide (Prontosil) was not essential as that complex substance was broken down in the body into the simpler compound para-amino-benzene-sulfonamide, or sulfanilamide, which was equally effective as a curative agent. In 1936 a group of English investigators substantiated Domagk's findings, and another group confirmed the conclusion of the French investigators and also demonstrated that sulfanilamide possessed chemotherapeutic properties capable of curing experimental meningococcal infections in mice.

Since 1935 probably hundreds of sulfonamide compounds that are derivatives of sulfanilamide have been prepared and subjected to extensive and intensive investigations as to their efficacy as chemotherapeutic agents. Although careful experimentation and clinical observation have shown remarkably few of them to be acceptable as chemotherapeutic agents those few are now used enormously in the treatment of infections caused by many types of infective organisms.

Chemical Composition.—In chemistry the word sulfonamide is used to designate a compound that is defined as an amide of a sulfonic acid.

An amide is a compound that results from the replacement of one of the atoms of hydrogen in ammonia (NH_3) by an element, or a radical. For example, when one of the hydrogen atoms in a molecule of ammonia is replaced by an atom of sodium (Na) the compound sodium amide ($NaNH_2$) is formed, or, when one of the hydrogen atoms in a molecule of ammonia is replaced by the acetyl radical CH_3CO) of acetic acid the compound acetamide (CH_3CONH_2) is formed.

The compounds known as sulfonic acids contain the sulfonic group (SO_3H) and are considered as derived from sulfuric acid (H_2SO_4) by the replacement of a hydroxyl group (OH) by a radical. Although organic sulfonic acids may be formed by oxidation of mercaptans (C_2H_5SH), compounds analogous to the alcohols (C_2H_5OH) and phenols (C_6H_5OH) but containing sulfur instead of oxygen, they usually are obtained by treating aromatic hydrocarbons with concentrated sulfuric acid. The process by which the sulfonic group is introduced is called sulfonation, an example being the formation of benzene-sulfonic acid. Benzene (C_6H_6) is an aromatic hydrocarbon and when warmed and shaken with concentrated sulfuric acid (H_2SO_4) it dissolves slowly and is converted into benzene-sulfonic acid as shown in the following equation:

$$\underset{\text{Benzene}}{C_6H_6} + \underset{\substack{\text{Sulfuric}\\\text{acid}}}{H_2SO_4} \rightarrow \underset{\substack{\text{Benzene-}\\\text{sulfonic acid}}}{C_6H_5SO_3H} + \underset{\text{Water}}{H_2O}$$

In the reaction one of the hydroxyl groups in the sulfuric acid unites with one of the hydrogen atoms in the benzene to form water, and there remains the sulfonic group (SO_3H) and the radical (C_6H_5) which unite to form benzene-sulfonic acid ($C_6H_5SO_3H$), the hydroxyl group lost from the acid in the formation of water having been replaced by the radical.

Although theoretically benzene-sulfonamide could be prepared directly from benzene-sulfonic acid by treating it with ammonia, it usually is prepared by the action of ammonia on benzene-sulfonyl-chloride which can be prepared by treating benzene-sulfonic acid with phosphorus pentachloride as shown in the following equation:

$C_6H_5SO_3H$	+	PCl_5	→	$C_6H_5SO_2Cl$	+	$POCl_3$	+	HCl
Benzene-sulfonic acid		Phosphorus pentachloride		Benzene-sulfonyl-chloride		Phosphorus oxychloride		Hydrochloric acid

Then, by treating benzene-sulfonyl-chloride ($C_6H_5SO_2Cl$) with ammonia (NH_3) benzene-sulfonamide ($C_6H_5SO_2NH_2$) is produced, the equation being:

$C_6H_5SO_2Cl$	+	NH_3	→	$C_6H_5SO_2NH_2$	+	HCl
Benzene-sulfonyl-chloride		Ammonia		Benzene-sulfonamide		Hydrochloric acid

In the reaction one of the hydrogen atoms in the molecule of ammonia unites with the atom of chlorine in the molecule of benzene-sulfonyl-chloride to form a molecule of hydrochloric acid, leaving benzene-sulfonamide remaining.

The therapeutically-active members of the so-called "sulfa drugs" that are now in use are all derivatives of sulfanilamide and a brief description of the chemical composition of that substance follows.

Sulfanilamide is defined as the amide of sulfanilic acid, an isomeric acid derived from aniline. Aniline is an oily, poisonous, basic liquid that occurs in small quantities in coal tar and in bone oil but is chiefly obtained by the reduction of nitrobenzene.

The hydrogen atoms in the molecule of the aromatic hydrocarbon benzene (C_6H_6) are readily replaced by the nitro group (NO_2) by the process of nitration. The nitration of benzene is accomplished by treating it with a mixture of concentrated nitric and sulfuric acids. The sulfuric acid itself does not react but it combines with the water formed in the reaction to prevent dilution of the nitric acid. In the reaction that takes place one of the hydrogen atoms in the molecule of benzene is replaced by the nitro group (NO_2). This nitro group results from the removal of one hydrogen atom and one oxygen atom in the molecule of nitric acid which then unite with the hydrogen atom from benzene to form water, the remaining compound being nitrobenzene. The equation of this reaction is:

C_6H_6	+	HNO_3	→	$C_6H_5NO_2$	+	H_2O
Benzene		Nitric acid		Nitro-benzene		Water

Nitrobenzene ($C_6H_5NO_2$) is converted into aniline ($C_6H_5NH_2$) by reduction with nascent hydrogen, the equation being:

$C_6H_5NO_2$	+	$6H$	→	$C_6H_5NH_2$	+	$2H_2O$
Nitro-benzene		Hydrogen		Aniline		Water

In the reduction of nitrobenzene it is necessary to use 6 atoms of hydrogen because 4 atoms are required to unite with 2 atoms of oxygen to form water (thereby removing the oxygen from the nitrobenzene) and 2 atoms are required to unite with the atom of nitrogen and satisfy its valence which changes from 5 to 3 in the process.

The sulfonation of aniline produces sulfanilic acid by the introduction of the sulfonic group (SO_3H) as a substituent for one of the hydrogen atoms in aniline. To produce sulfanilic acid, aniline is first treated with concentrated sulfuric acid to form the solid aniline acid-sulfate, the equation being:

$C_6H_5NH_2$	+	H_2SO_4	→	$C_6H_5NH_3SO_4H$
Aniline		Sulfuric acid		Aniline acid-sulfate

By heating aniline acid-sulfate at 200° sulfanilic acid and water is formed, the equation being:

$$\underset{\text{Aniline acid-sulfate}}{C_6H_5NH_3SO_4H} + \text{heat} \rightarrow \underset{\text{Sulfanilic acid}}{C_6H_4NH_2SO_3H} + \underset{\text{Water}}{H_2O}$$

Sulfanilamide is not prepared directly from sulfanilic acid but usually from acetanilide (phenyl-acetamide), an acetyl derivative of aniline. By reacting acetanilide with chlorosulfonic acid, acetylsulfanilyl chloride is formed. This substance is next converted to acetylsulfanilamide by treatment with ammonia. Finally, the acetyl group (CH_3CO) is removed from acetylsulfanilamide by hydrolysis with acidulated water and sulfanilamide remains. The following equations show these reactions in the order in which they occur:

1. $$\underset{\text{Acetanilide}}{C_6H_5NHCH_3CO} + \underset{\text{Chlorosulfonic acid}}{ClSO_3H} \rightarrow \underset{\text{Acetylsulfanilyl acid}}{C_6H_4NHCH_3COSO_2Cl} + \underset{\text{Water}}{H_2O}$$

2. $$\underset{\text{Acetylsulfanilyl chloride}}{C_6H_4NHCH_3COSO_2Cl} + \underset{\text{Ammonia}}{NH_3} \rightarrow \underset{\text{Acetylsulfanilamide}}{C_6H_4NHCH_3COSO_2NH_2} + \underset{\text{Hydrochloric acid}}{HCl}$$

3. $$\underset{\text{Acetylsulfanilamide}}{C_6H_4NHCH_3COSO_2NH_2} + \underset{\text{Water (acidulated)}}{H_2O} \rightarrow \underset{\text{Sulfanilamide}}{NH_2C_6H_4SO_2NH_2} + \underset{\text{Acetic acid}}{CH_3COOH}$$

Therapeutics of the sulfonamides.

Mode of Action.—Exact information as to how the sulfonamide compounds act is lacking but enough data have been obtained to warrant certain statements. The sulfonamides in general do not kill bacteria. They prevent the multiplication of bacteria, which is essential to their spread in the body, and thereby render them more susceptible to the natural defenses of the body. This action in preventing bacterial reproduction is known as *bacteriostasis* in contrast to the action of certain substances which actually kill bacteria and are said to be *bactericidal.*

Certain substances have the property of preventing the action of sulfonamides. Among these is para-aminobenzoic acid (commonly referred to as PABA), a substance essential in the bacterial enzyme system. Some of the local anesthetics, of which procaine is a good example, are closely related chemically to para-aminobenzoic acid and when introduced into wounds with a sulfonamide may inhibit the latter's action. It has also been demonstrated that pus and dead tissue contain substances which inhibit the action of the sulfonamides. For this reason the administration of sulfonamides does not remove the necessity of properly draining abscesses and of removing dead tissue.

Not all bacteria are susceptible to the action of the sulfonamides. Those which are susceptible in general are the aerobic organisms, which belong to the gram-positive group, as well as the gram-negative diplococci (meningococcus and gonococcus), the colon bacillus and the dysentery bacilli. Other gram-negative bacteria are not susceptible to these compounds. The only filtrable virus that seems to be susceptible to the action of the sulfonamides is the one which produces lymphogranuloma venereum. Certain sulfonamide compounds are more active against one type of bacteria than against others. Also, certain organ-

isms are more susceptible to the action of these drugs than others. Staphylococcus infections, although in certain cases amenable to sulfonamide therapy, are much more resistant than infections caused by the hemolytic streptococcus or the pneumococcus.

The matter of sulfonamide susceptibility and resistance will be discussed more fully in connection with the therapeutic uses of the individual members of the series.

Certain strains of bacteria, ordinarily sulfonamide-susceptible, can develop a resistance to these drugs. Such organisms are known as "sulfonamide-fast" bacteria. An organism that is "fast" to one of these compounds is usually "fast" to all.

UNTOWARD EFFECTS.—The administration of the sulfonamide compounds is not without danger. In certain susceptible individuals they may produce serious untoward effects, among which the most important are:

1. Anemia.—An anemia of mild degree almost always follows the prolonged administration of these drugs. Anemia may, however, develop very rapidly and should be watched for by frequent observations of the patient's color and frequent estimations of the hemoglobin content of the blood.

2. Acute hemolytic reactions.—These are characterized by rapid destruction of red blood cells with the development of profound anemia. Hemoglobin, the pigment contained in the red blood cells, is poured into the blood stream and some of it is changed to bilirubin, producing jaundice. Some of the hemoglobin is eliminated in the urine. When it comes in contact with acid urine in the tubules of the kidney, acid hematin is formed which may precipitate and block the tubules, causing a stoppage of the flow of urine (anuria). Clinically this complication (like the similar reaction that may occur after transfusion with incompatible blood) is characterized by chills, fever, jaundice, and the passage of scanty dark-colored urine.

3. Hepatitis.—In rare instances the sulfonamides may actually destroy the liver cells causing severe jaundice to develop.

4. Granulocytopenia.—In this condition the polymorphonuclear leucocytes may be greatly reduced in number or even may disappear from the circulating blood. When it occurs, the local resistance of the tissues of the mouth to Vincent's organism (trench mouth) is greatly lowered, and ulcers of the tongue and mucous membrane of the mouth often form. It is because of the danger of granulocytopenia that frequent determinations of the white blood cell and differential counts are advised when sulfonamides are being given.

5. Cerebral complications.—A certain amount of dulling of the mental processes frequently results from the effect of these drugs. In rare instances, however, one may encounter delirium with maniacal behavior or hallucinations or delusions.

In the event that one of these drug reactions should occur during treatment with sulfonamides, the drug should be immediately discontinued. Fluids should be forced by mouth and, if necessary, by vein. In the presence of a hemolytic reaction the urine should be rendered alkaline by sodium bicarbonate to avoid as much as possible the plugging of the renal tubules by acid hematin. In the presence of jaundice the diet should be low in fat and high in carbohydrate. In the presence of agranulocytosis as much crude liver or liver extract as possible should be given by mouth, liver extract should be given intramuscularly, and the mouth should be kept as clean as possible with hot saline irrigations and mouth washes.

6. Nausea.—This occurs in over 50 percent of patients receiving sulfapyridine, in an appreciable number receiving sulfanilamide, in about 4 percent of those

receiving sulfathiazole, and rarely in those receiving sulfadiazine and sulfaguanidine. Therefore, sulfapyridine should not be used if sulfathiazole or sulfadiazine is available. If nausea occurs when giving sulfathiazole, change to sulfadiazine.

The mechanism of some of these reactions is not understood. Some of them seem to be sensitization phenomena, in others the sulfonamide may either interfere with the metabolism of the cells of certain organs or may deprive those cells of certain substances necessary to their metabolism.

Much more common than the serious untoward reactions just described is *mechanical damage to the kidney tubules* from crystals. The sulfonamides are acetylated (combined with acetic acid) in the body to form an acetyl sulfonamide. Acetyl sulfonamides are less soluble, especially in the presence of acids, than the original compounds and tend to precipitate out of solution with the formation of crystals. This is of great importance in the tubules of the kidneys and in the ureters, where crystals may injure the delicate walls with the production of bleeding (hematuria), or may even block the tubules and prevent the passage of urine. As the acetyl forms of these compounds are much more soluble in alkaline urine, this complication can be largely prevented by administering enough sodium bicarbonate with the sulfonamides to maintain an alkaline urine. It is important for the same reason that enough fluid be given to the patient to maintain a daily output of urine of at least 1,000 cc. The output of urine must always be measured during the administration of the usual therapeutic doses of the sulfonamides. The presence of this complication will be recognized by the passage of bloody urine containing large numbers of sulfonamide crystals. When the ureters contain many crystals, there may be pain simulating mild bilateral ureteral colic. Treatment consists of immediate withdrawal of the drug and the administration of large amounts of fluids and sodium bicarbonate (4 Gm. every 4 hours) or an appropriate dose of some other alkali. This complication almost never occurs when sulfanilamide is being used.

Finally, there are certain patients who develop *hypersensitivity* (an allergic reaction) to these compounds. Most common reactions of this type occur in the skin. Mild rashes may appear, particularly on the neck and shoulders and over the extensor surfaces of the elbows and knees and on the skins. In the last three places it is not unusual for the rash to have the appearance of erythema nodosum (raised, tender, bluish-red blotches, which usually are distributed symmetrically) or of cellulitis (red, tender areas which, unlike true cellulitis are usually not hot). On the other hand a generalized rash may develop which has much the appearance of German measles. Sometimes a conjunctivitis will accompany the rash, and fever is not infrequent. The development of skin sensitivity is favored by exposure to ultraviolet light (this applies especially to sulfathiazole), and patients receiving sulfonamides should be kept out of the sun. Hypersensitive reactions to these drugs may be accompanied by fever, and the presence of fever in a patient receiving a sulfonamide whose infection is under control should lead one to suspect that it may be caused by the drug.

Hypersensitive reactions are often specific for the drug being given and a change to another sulfonamide may be possible.

Certain of the sulfonamide compounds may be very irritating when used locally in wounds. In general, sulfanilamide is the least irritating and is the drug of choice for local application. Sulfathiazole in powder form is very irritating and should never be introduced into the peritoneal cavity or the brain.

NAVY USAGE.—The sulfonamide compounds that are in common use in the Navy are the following: Sulfadiazine, sulfathiazole, sulfapyridine, sulfanilamide,

sulfaguanidine, and succinylsulfathiazole (frequently called sulfasuxidine), which are used orally, sodium sulfadiazine, which is used parenterally, and sulfanilamide powder or crystals, which is used for local application.

For the information and guidance of hospital corpsmen on independent duty and others who may be required to use sulfonamide compounds in the absence of medical officers, the Bureau of Medicine and Surgery has issued an outline of instructions relative to such use. This outline states that modification of the instructions may have to be made from time to time to provide for the use of new, more effective, or safer sulfonamides, as well as for changes indicated as a result of research or clinical observations on the ones now in use. The outline follows.

Sulfonamides may be used for the following conditions: Wounds and burns; pneumonia, meningitis; streptococcus sore throat and tonsillitis; ear and mastoid infections; dysentery; gonorrhea; chancroid (soft chancre), and chancroidal bubo; lymphogranuloma venereum (tropical bubo); boils and carbuncles; cellulitis; lymphangitis, septicemia ("blood poisoning").

A. WOUNDS AND BURNS.—For large and penetrating wounds and extensive burns, give *sulfadiazine*, 4 Gm. (8 tablets) with first-aid treatment to prevent infection. If care by medical personnel does not become available within a few days and the patient develops local signs of infection (pain, redness, swelling) and fever, give *sulfadiazine* as follows: First dose, 4 Gm. (8 tablets); then 1 Gm. every 4 hours until improvement occurs, when the dose should be reduced to 1 Gm. every 6 hours, and continued for 3 days.

B. PNEUMONIA.—The characteristic symptoms of pneumonia are: Chills followed by fever; cough, and pain in chest; rapid pulse and rapid respiration; later rusty or bloody sputum.

Give *sulfadiazine*, first dose, 4 Gm. (8 tablets); then 1 Gm. every 4 hours, day and night, until the fever, pain, and other serious symptoms have subsided; and then for 3 more days.

C. MENINGITIS.—The characteristic symptoms of meningitis are: Headache and fever, sometimes chills; later stiff, painful neck.

Give *sulfadiazine*, first dose, 4 Gm. (8 tablets); then 1 Gm. every 4 hours, day and night, until the temperature has been normal for 7 days.

D. EAR AND MASTOID INFECTIONS.—The characteristic symptoms of these conditions are: Pain in the ear; later discharge of pus; sometimes swelling and tenderness over the mastoid and fever.

Give *sulfadiazine*, first dose, 4 Gm. (8 tablets); then 1 Gm. every 4 hours, day and night, until symptoms relieved and temperature normal; then continue for 3 more days.

E. DYSENTERY.—There are two types of dysentery, bacillary and amoebic. Bacillary dysentery is epidemic, likely to affect not one person but a large number within a few days. The onset is sudden with fever and abdominal cramps followed by loose stools, at first watery, later containing mucus and blood. Amoebic dysentery is not epidemic, but occurs sporadically from time to time. It is a "walking dysentery," the patient not being very sick, although perhaps having 10 or more bowel movements daily with blood and mucus.

Sulfonamides are effective only for bacillary dysentery. *Succinylsulfathiazole* or *sulfaguanidine*, may be used if available, first dose, 6 Gm. (12 tablets), then 3 Gm. every 4 hours, night and day, until number of stools per day is reduced to 5 or less; then give 3 Gm. only every 8 hours until stools have been normal for 3 days.

However, *sulfadiazine* is a safer and more effective drug. It should be given as follows: First dose, 2 Gm. (4 tablets), then 1 Gm. every 4 hours, night and day,

for 3 days, or less if dysentery stops; then 1 Gm. 3 times daily until stools have been normal for 3 days.

If there is no improvement within 3 days, discontinue the drug as it is not likely that the dysentery is bacilliary in type, and an additional amount of sulfonamides will be of no value. Use instead bismuth subcarbonate, 1 level teaspoonful every 3 hours until stools are formed.

F. GONORRHEA.—The characteristic symptoms are: Purulent discharge from the urethra following venereal exposure.

Give *sulfathiazole*, 1 Gm. (2 tablets), 4 times a day, for 5 days; a total of 20 Gm. If sulfathiazole is not available, use *sulfadiazine* or *sulfapyridine*.

G. CHANCROID (*soft chancre*) and *CHANCROIDAL BUBO.*—The characteristic symptoms are: Single or multiple ulcers on genitalia, occurrring from 3 to 14 days after venereal exposure.

Give *sulfathiazole* or *sulfadiazine*, 1 Gm. (2 tablets), 4 times a day for 5 days; a total of 20 Gm.

H. LYMPHOGRANULOMA VENEREUM (*tropical bubo*).—The characteristic symptoms are: Enlarged, tender glands in the groin (bubo), occurring from 10 to 30 days after venereal exposure.

Give *sulfathiazole* or *sulfadiazine*, 1 Gm. (2 tablets), 3 times daily for 5 days, then 1 Gm. twice a day for another 5 days.

I. BOILS AND CARBUNCLES.—For small boils, sulfonamides are not necessary; hot boric acid dressings usually suffice. For large or multiple boils and carbuncles, give *sulfadiazine*, first dose, 4 Gm. (8 tablets), followed by 1 Gm. every 4 hours until acute inflammation has disappeared.

J. CELLULITUS, LYMPHANGITIS, SEPTICEMIA (*"blood poisoning"*).—The characteristic symptoms are: Red streaks extending from infected, swollen, painful wound.

Give *sulfadiazine*, first dose, 4 Gm. (8 tablets), then 1 Gm. every 4 hours until the spread of the infection has been stopped; then 1 Gm. every 6 hours for 5 days. Do not neglect local treatment with hot boric acid dressings.

In all the foregoing conditions, *sulfathiazole* may be used when *sulfadiazine* has been recommended. The dosage for the two drugs is the same.

The sulfonamide tablets should be given with liquids (water, milk, fruit juices). Should the patient have difficulty in swallowing the tablets, they may be broken up and mixed with the liquid. While taking sulfonamides, the patient should receive enough water or other liquids (about 3 quarts) to produce at least 3 pints (1,500 cc.) of urine per day. *This is of utmost importance.* Measure and keep a record of the daily amount of urine. Should the urine become very scanty in spite of adequate fluid intake, discontinue the drug immediately. The sulfonamides should also be stopped if the patient develops other untoward symptoms, such as skin rash, jaundiced sclera (yellowish color of the white of the eye), or very pale mucous membranes. If the fever has disappeared and then recurs while the sulfonamide is being given, it is very likely a drug fever and the sulfonamide should be discontinued.

Sulfanilamidum, Sulfanilamide, $C_6H_8N_2O_2S$, U. S. P.—When dried at 100° C. for 4 hours, it contains not less than 99 per cent of $C_6H_8N_2O_2S$. Preserve it in well-closed, light-resistant containers.

PROPERTIES: It occurs as white crystals, granules, or powder, is odorless, and is affected by light. One Gm. dissolves in about 125 cc. of water, in about 37 cc. of alcohol, and in about 5 cc. of acetone, at 25° C. It is also soluble in glycerin, hydrochloric acid, and aqueous solutions of potassium and sodium hydroxides, and is very soluble in boiling water. It is insoluble in chloroform, ether, and

benzene. It melts at between 164.5° and 166.5° C., developing an intense violet blue color. On further heating the odors of ammonia and aniline are evolved.

ACTION AND USES: There is some question as to the value of applying any of the sulfonamides locally because substances in pus inhibit their bacteriostatic action. However, in fresh wounds, before infection has developed, they may check the growth of the organisms for a time. If used, the powder should be dusted freely into the wound. It should not be used on burns involving large areas, as it is possible that dangerous amounts may be absorbed. The concentration of the sulfonamide in the blood produced by oral or parenteral administration and therefore in the tissues surrounding a wound is more important in the prevention of bacterial invasion or severe spreading than is the "sulfa" in the wound.

The action of the sulfonamides depends not on the individual dose but upon the actual concentration of the drug in the body. The concentration of the drug in the blood can be accurately measured and is a useful guide to dosage. An effective level for most severe infections is between 5 and 10 mg. per 100 cc. In meningococcus infections it is safer to achieve a level of between 10 and 15 mg. per 100 cc. during the first 2 or 3 days.

The laboratory methods for determining blood levels can be found in standard publications on blood chemistry.

Tabellae Sulfanilamidi, Sulfanilamide Tablets, U. S. P.—They contain not less than 95 per cent and not more than 105 per cent of the labeled amount of sulfanilamide ($C_6H_8N_2O_2S$) and should be preserved in well-closed containers. The sulfanilamide tablets usually available contain 0.3 or 0.5 Gm. (5 or 7½ grains) of sulfanilamide.

ACTION AND USES: Although effective against hemolytic streptococci and meningococci, this drug is inferior to the other drugs of the series in potency and is not effective against pneumococci and staphylococci. Its use is accompanied by a greater number of serious reactions. Patients receiving it often have a bluish color because it changes some of the hemoglobin in the red blood cells to methemoglobin. Since the introduction of more satisfactory sulfonamides it is rarely used except for local application. It does not, however, produce urinary complications and therefore, when hematuria occurs in a patient being treated with another sulfonamide for a hemolytic streptococcus or meningococcus infection before it is considered safe to discontinue the drug, it is wise to change to sulfanilamide after making sure that the urine is alkaline.

Average dose: 2 Gm. or 30 grains.

The initial dose may be 4 Gm. (or 60 grains) followed by subsequent doses of 1 Gm. (or 15 grains) every 4 hours, day and night, on the first day, 1 Gm. (or 15 grains) every 6 hours, day and night, on the second day, and 1 Gm. (or 15 grains) every 8 hours, day and night, on the third and subsequent days.

Sulfapyridinum, Sulfapyridine, $C_{11}H_{11}N_3O_2S$, U. S. P.—When dried at 100° C. for 4 hours, it contains not less than 99 per cent of $C_{11}H_{11}N_3O_2S$. Preserve it in well-closed, light-resistant containers.

PROPERTIES: A pyridyl derivative of sulfanilamide, sulfapyridine occurs as white or faintly yellowish white crystals, granules, or powder. It is odorless or nearly so, is stable in air, and slowly darkens on exposure to light. One Gm. dissolves in about 3,500 cc. of water, in about 440 cc. of alcohol, and in about 6,500 cc. of acetone, at 25° C. It is freely soluble in dilute mineral acids and in aqueous solutions of potassium and sodium hydroxides. It melts at between 191° and 193° C., developing a brown color. On further heating, yellow fumes appear and an odor of sulfur dioxide is evolved.

ACTION AND USES: See under Tabellae Sulfapyridini.

Average dose: 2 Gm. or 30 grains.

Tabellae Sulfapyridini, Sulfapyridine Tablets, U. S. P.—They contain not less than 95 per cent and not more than 105 per cent of the labeled amount of sulfapyridine ($C_{11}H_{11}N_3O_2S$) and should be preserved in well-closed containers. The sulfapyridine tablets usually available contain 0.3 or 0.5 Gm. (5 or 7½ grains of sulfapyridine.

ACTION AND USES: The action and uses of sulfapyridine tablets and the frequency of urinary complications are approximately the same as those of sulfadiazine and sulfathiazole (*q.v.*). Severe untoward reactions are slightly more frequent. The occurrence of nausea in over half the patients receiving sulfapyridine makes it a definitely inferior drug and it is also less effective against bacteria.

Average dose: 2 Gm. or 30 grains.

The initial dose may be 4 Gm. (or 60 grains) followed by subsequent doses of 1 Gm. (or 15 grains) every 4 hours, day and night, on the first day, 1 Gm. (or 15 grains) every 6 hours, day and night, on the second day, and 1 Gm. (or 15 grains) every 8 hours, day and night, on the third and subsequent days.

Sulfathiazolum, Sulfathiazole, $C_9H_9N_3O_2S_2$, U. S. P.—When dried at 100° C. for 4 hours, it contains not less than 99 per cent of $C_9H_9N_3O_2S_2$. Preserve it in well-closed, light-resistant containers.

PROPERTIES: A thiazole derivative of sulfanilamide, sulfathiazole occurs as white or faintly yellowish white crystals, granules, or powder. It is odorless or nearly so, is stable in air, and slowly darkens on exposure to light. One Gm. dissolves in about 1,700 cc. of water, and in about 200 cc. of alcohol, at 25° C. It is soluble in acetone and freely soluble in dilute mineral acids, in aqueous solutions of potassium and sodium hydroxides, and in ammonia test solution. It melts between 200° and 204° C., developing a brown to red color. On further heating the odors of ammonia, aniline, and hydrogen sulfide are evolved.

ACTION AND USES: See under Tabellae Sulfathiazoli.

Average dose: 2 Gm. or 30 grains.

Tabellae Sulfathiazoli, Sulfathiazole Tablets, U. S. P.—They contain not less than 95 per cent and not more than 105 per cent of the labeled amount of sulfathiazole ($C_9H_9N_3O_2S_2$) and should be preserved in well-closed containers. The sulfathiazole tablets usually available contain 0.3 or 0.5 Gm. (5 or 7½ grains) of sulfathiazole.

ACTION AND USES: This drug is slightly preferred by most physicians to sulfadiazine in the treatment of gonorrheal infections. Otherwise its action and uses are the same as those of sulfadiazine. Untoward reactions and urinary complications are about as common as with sulfadiazine, except that nausea occurs with greater frequency. Where sulfadiazine is not available, sulfathiazole is the drug of choice. It is effective in meningitis.

Average dose: 2 Gm. or 30 grains.

The initial dose may be 4 Gm. (or 60 grains) followed by subsequent doses of 1 Gm. (or 15 grains) every 4 hours, day and night, on the first day, 1 Gm. (or 15 grains) every 6 hours, day and night, on the second day, and 1 Gm. (or 15 grains) every 8 hours, day and night, on the third and subsequent days, but as sulfathiazole is excreted quite rapidly it is wise to administer it at regular 4-hour intervals.

Sulfadiazinum, Sulfadiazine, $C_{10}H_{10}N_4O_2S$, U. S. P.—When dried at 100° C. for 4 hours, it contains not less than 99 per cent of $C_{10}H_{10}N_4O_2S$. Preserve it in well-closed, light-resistant containers.

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PROPERTIES: A pyrimidyl derivative of sulfanilamide, sulfadiazine occurs as a white or slightly yellow powder. It is odorless or nearly so, is stable in air, and slowly darkens on exposure to light. One Gm. dissolves in about 13,000 cc. of water at 25° C. and it is sparingly soluble in alcohol and acetone. It is freely soluble in dilute mineral acids and in aqueous solutions of potassium and sodium hydroxides, and in ammonia test solution. It melts at between 250° and 256° C. with decomposition, developing a reddish-brown color. The fumes evolved during decomposition do not discolor moistened lead acetate paper, which distinguishes it from sulfathiazole.

ACTION AND USES: See under Tabellae Sulfadiazini.

Average dose: 2 Gm. or 30 grains.

Tabellae Sulfadiazini, Sulfadiazine Tablets, U. S. P.—They contain not less than 95 per cent and not more than 105 per cent of the labeled amount of sulfadiazine and should be preserved in well-closed, light-resistant containers. The sulfadiazine tablets usually available contain 0.3 or 0.5 Gm. (5 or 7½ grains) of sulfadiazine.

ACTION AND USES: Sulfadiazine is considered the best all-round one of the sulfonamide drugs. It is highly effective against streptococci, pneumococci, meningococci, and gonococci, and is as effective as any sulfonamide drug against staphylococci, gas bacilli, dysentery organisms, and colon bacilli. Serious toxic reactions are infrequent with use of this drug, and rarely does it produce nausea. Urinary complications are not infrequent, however, and great care must be exercised to see that there is an adequate flow of alkaline urine. It must not be given parenterally, i. e., by intramuscular or intravenous injection.

Average dose: 2 Gm. or 30 grains.

The initial dose may be 4 Gm. (or 60 grains) followed by subsequent doses of 1 Gm. (or 15 grains) every 4 hours, day and night, on the first day, 1 Gm. (or 15 grains) every 6 hours, day and night, on the second day, and 1 Gm. (or 15 grains) every 8 hours, day and night, on the third and subsequent days.

Sulfadiazinum Sodicum, Sulfadiazine Sodium, (Sodium Sulfadiazine), $C_{10}H_9N_4O_2SNa$, U. S. P.—When dried at 105° C. for 4 hours, it contains not less than 99 per cent of $C_{10}H_9N_4O_2SNa$. Preserve it in tight, light-resistant containers.

PROPERTIES: Sulfadiazine sodium is a sodium salt of sulfadiazine that occurs as a white powder and is affected by light. One Gm. dissolves in about 2 cc. of water at 25° C. and it is only slightly soluble in alcohol. On prolonged exposure to humid air, it absorbs carbon dioxide with the liberation of sulfadiazine and becomes incompletely soluble in water.

ACTION AND USES: The same as for sulfadiazine. To make a solution for parenteral use the desired amount of the powder is added to sterile distilled water or sterile saline solution. The drug may be given intravenously in solutions not more concentrated than 5 per cent, or intramuscularly or subcutaneously in solutions not more concentrated than 2 per cent.

Average dose: 2 Gm. or 30 grains.

Sulfaguanidinum, Sulfaguanidine, $C_7H_{10}O_2N_4S.H_2O$, U. S. P.—When dried at 105° C. for 4 hours, it contains not less than 99 per cent of $C_7H_{10}N_4O_2S$. Preserve it in well-closed, light-resistant containers.

PROPERTIES: A guanyl derivative of sulfanilamide, sulfaguanidine occurs as a white, needle-like, crystalline powder. It is odorless or nearly so, is stable in air, and slowly darkens on exposure to light. One Gm. dissolves in about 1,000 cc. of water at 25° C. and in about 25 cc. at 100° C.; it is sparingly soluble in alcohol and in acetone, and freely soluble in dilute mineral acids. It is insoluble in

aqueous solutions of sodium hydroxide at room temperature. When dried at 105° C. for 4 hours it melts at between 190° and 193° C. If 5 cc. of a 1 in 5 aqueous solution of sodium is added to 0.2 Gm. of sulfaguanidine the sulfaguanidine does not dissolve, but, when heated to boiling, it dissolves and an odor of ammonia is evolved, distinguishing it from sulfanilamide, sulfathiazole, sulfapyridine, and sulfadiazine, all of which do dissolve in cold sodium hydroxide solution and do not evolve ammonia when boiled.

ACTION AND USES: See last three paragraphs following "Succinylsulfathiazole Tablets".

Average dose: 2 Gm. or 30 grains.

Tabellae Sulfaguanidini, Sulfaguanidine Tablets, U. S. P.—They contain not less than 95 per cent and not more than 105 per cent of the labeled amount of sulfaguanidine ($C_7H_{10}N_4O_2S.H_2O$) and should be preserved in well-closed, light-resistant containers. The sulfaguanidine tablets usually available contain 0.3 or 0.5 Gm. (5 or 7½ grains) of sulfaguanidine.

ACTION AND USES: See last three paragraphs following "Succinylsulfathiazole Tablets."

Average dose: 2 Gm. or 30 grains.

Succinylsulfathiazolum, Succinylsulfathiazole, $C_{13}H_{13}N_3O_5S_2.H_2O$, **U. S. P.**—When dried at 100° C. for 6 hours, it contains not less than 99 per cent of $C_{13}H_{13}N_3O_5S_2$. Preserve it in well-closed, light-resistant containers. Frequently called Sulfasuxidine.

PROPERTIES: A succinyl-thiazole derivative of sulfanilamide, succinylsulfathiazole occurs as a white or yellowish white, crystalline powder. It is odorless, stable in air, and slowly darkens on exposure to light. One Gm. dissolves in about 4,800 cc. of water at 25° C.; it is soluble in aqueous solutions of alkali hydroxides and in solutions of sodium bicarbonate with the evolution of carbon dioxide, sparingly soluble in alcohol and acetone, and insoluble in chloroform and ether. It melts with decomposition at between 185° and 195° C., and when about 50 mg. are carefully heated in a small test tube over an open flame until melted, pungent fumes that discolor moistened lead acetate paper are evolved.

ACTION AND USES: See last three paragraphs following "Succinylsulfathiazole Tablets."

Average dose: 2 Gm. or 30 grains.

Tabellae Succinylsulfathiazoli, Succinylsulfathiazole Tablets, U. S. P.—They contain not less than 95 per cent and not more than 105 per cent of the labeled amount of succinylsulfathiazole, $C_{13}H_{13}N_3O_5S_2.H_2O$, and should be preserved in well-closed, light-resistant containers. The succinylsulfathiazole tablets usually available contain 0.3 or 0.5 Gm. (5 or 7½ grains) of succinylsulfathiazole. Frequently called Sulfasuxidine Tablets.

ACTION AND USES: See last three paragraphs following.

Average dose: 2 Gm. or 30 grains.

Sulfaguanidine and Succinylsulfathiazole (Sulfasuxidine) are absorbed with considerable difficulty through the wall of the intestine and therefore by their use a high intestinal-sulfonamide concentration can be achieved with a low blood level. They are of value (1) in rendering the intestinal tract relatively free of bacteria of the colon group as a preparation for operation on the large bowel; (2) in the treatment of bacillary dysentery; and (3) in the treatment of bacillary dysentery carriers.

They are not to be preferred to sulfadiazine or sulfathiazole in the treatment of acute bacillary dysentery. They are not effective in the *Salmonella* infections, typhoid fever, amoebic dysentery, and cholera.

In dysentery an initial dose of 6 Gm. (or 90 grains), then 3 Gm. (or 45 grains) every 4 hours, day and night, until the number of stools per day is reduced to 5 or less, and then 3 Gm. (or 45 grains) every 8 hours until the stools have been normal for 3 days.

PENICILLIN.

SOURCE, NATURE, AND IMPORTANCE OF PENICILLIN.—Penicillin is an antibiotic agent produced by the mold, *Penicillium notatum*, when cultivated on suitable media and under certain conditions. It is extracted from the medium, purified, dried, tested for absence of pyrogens (fever-producing substances) and sterility, and packaged in sterile ampoules under aseptic conditions. At present it is supplied as the sodium salt, which occurs as a fine powder varying in color from light yellow to dark brown. Other salts of penicillin may be available later.

The remarkable results obtained with penicillin in the treatment of certain infections promise to establish this new drug as the most outstanding medical discovery of the World War II era.

HISTORICAL DEVELOPMENT.—In 1929, Fleming, an English bacteriologist, first realized the significance of the fact that bacterial cultures which became contaminated by a certain mold showed definite inhibition of their growth. The way was opened for the discovery of a powerful new antibacterial substance. Fleming isolated the mold which later was identified as *Penicillium notatum*. He gave the name penicillin (pronounced pen-i-sill'-in) to the antibacterial substance derived from it and found that, in the laboratory test tube, the substance was active against staphylococci, streptococci, and pneumococci.

Because penicillin was extremely unstable and difficult to produce in large amounts, little further research on the mold was done until 1940. At this time Florey and his colleagues, working at Oxford, announced the important discovery that penicillin is active *in vivo* (in a living organizm) as well as *in vitro*.

In 1941 Florey visited the United States through an arrangement with the Rockefeller Foundation. With his assistance the U. S. Department of Agriculture initiated studies on the culture-growth characteristics of the mold. At the same time, in cooperation with the National Research Council and the Committee on Medical Research of the Office of Scientific Research and Development, Florey enlisted the cooperation of several commercial companies in undertaking the production of penicillin.

Large-scale production proved difficult because of the fact that only small amounts of the active substance are formed during the metabolism of the mold after days of growth. This and many other problems were gradually overcome with the result that the commercial production of penicillin began to increase rapidly in the last quarter of 1943.

A system of rationing under control of the War Production Board was necessary to ensure proper distribution of the available supply. Under this plan approximately 85 percent of the penicillin produced was allocated to the armed forces. The balance was allocated for clinical research and chemical investigation, with a limited quantity available to the civilian population for the treatment of emergencies.

Penicillin is now being manufactured by 13 American and 2 Canadian firms in continually increasing amounts with the prospect that all essential requirements for the drug may soon be met.

"HOME-GROWN" CULTURES.—During the period of limited production of penicillin, many individuals attempted to use "home-grown" cultures of the mold, or

products of such cultures, in the treatment of wounds and infections. Results were unsatisfactory as the particular mold which produces the active antibacterial agent can be cultured only under carefully controlled laboratory conditions.

CHEMICAL CHARACTERISTICS.—Although penicillin can be produced in pure crystalline form, its structural chemical formula is not yet definitely known. When this has been determined, artificial production by synthesis may be possible.

Penicillin is a nitrogenous compound (probably a protein) in which is found an organic acid with the probable formula $C_{14}H_{19}NO_6$ or $C_{14}H_{17}NO_5H_2O$. The compound is unstable presumably because of the presence in it of free carboxyl (COOH) groups that readily undergo change.

FORM IN WHICH PENICILLIN IS SUPPLIED.—Penicillin is supplied to the Navy in the form of the sodium salt, as a sterile powder in ampoules, 100,000 units per ampoule, and is listed in the Supply Catalog, Medical Department, U. S. Navy, as follows:

Stock No.	*Item*	*Unit*
S1–1130	Penicillin, sodium, crystalline, 100,000 Oxford units in ampoule (5 ampoules in box) (Potency—3 months)	Ampoule

UNIT OF MEASUREMENT OF DOSAGE.—Penicillin is not measured by weight, but by an arbitrary standard of efficiency known as the Oxford unit.

An Oxford unit is the amount of penicillin which completely inhibits the growth of a test organism, *Staphylococcus aureus*, under certain specified conditions. One hundred thousand Oxford units as contained in the standard ampoule is equivalent to 60 milligrams of pure crystalline sodium penicillin.

STORAGE AND STABILITY.—The dried powder, when contained in ampoules, is quite stable at ordinary room temperature, but high temperatures and prolonged exposure at room temperature cause significant deterioration. To assure maximum potency, the ampoules therefore should be stored in refrigeration. Though the penicillin expiration date is based upon preservation of penicillin at ordinary refrigeration temperatures (4° C.), freezing temperatures will prolong the duration of potency. In the storage of penicillin, freezing temperatures may be used to advantage by the placing of penicillin in frozen meat and food compartments when these are available. In liquid form penicillin is extremely unstable. Solutions should therefore be made up preferably just before administration, or at least daily, and then kept under refrigeration at about 4° C.

ACTION.—While the rapidity with which some infections are eliminated by the use of penicillin suggests that the drug exerts a direct bactericidal action, it is the general opinion that the action of penicillin is principally bacteriostatic with a high degree of specificity; that is to say, penicillin does not actually kill the organisms which are susceptible to its action, but inhibits their multiplication and makes them more vulnerable to the body's mechanisms for combating infections.

The organisms which have been found to be susceptible to the action of penicillin are as follows:

Streptococci
Staphylococci
Diplococcus pneumoniae (pneumococcus)
Neisseria gonorrhoeae (gonococcus)
Neisseria intracellularis (meningococcus)
Neisseria catarrhalis (micrococcus catarrhalis)
Treponema pallidum (organism causing syphilis)

The following-named organisms have been found to be *not* susceptible to the action of penicillin:

Eberthella typhosa (typhoid bacillus)
Shigella dysenteriae (dysentary bacillus)
Pseudomonas aeruginosa (bacillus pycocyaneous; "bacillus of green or blue pus")
Monilia (parasitic fungi)
Rickettsia (organisms causing typhus fever, Rocky Mountain spotted fever, etc.)
Protozoan parasites causing amoebic dysentery, African sleeping sickness, etc.
Escherichia coli (colon bacillus)
Hemophilus influenzae (influenza bacillus)
Klebsiella pneumoniae (bacillus pneumoniae; Friedlander's bacillus)
Mycobacterium tuberculosis (*hominis*) (tuberculosis bacillus)
Plasmodia (organisms causing malaria)

PHARMACOLOGY.—Penicillin is rapidly inactivated by the hydrochloric acid of the gastric juice, and very little, if any, is absorbed following rectal instillation. Therefore to secure adequate absorption, penicillin must be given parenterally, either by intravenous or by intramuscular injection. Higher blood levels are obtained following intravenous injections, but more evenly sustained levels result from intramuscular administration.

Following injection, penicillin is rapidly excreted by the kidneys. An average of 58 percent of the amount injected is found in the urine at the end of an hour, and even when large amounts are given in a single injection, the blood will be practically cleared of penicillin at the end of 3 hours.

After intravenous or intramuscular injection, very little, if any, penicillin passes into the cerebrospinal fluid or into any of the various serous cavities of the body, i. e., the pleural cavity and joints. Therefore, when meningitis, suppurative arthritis, or empyema is to be treated, injection of the penicillin solution directly into the appropriate cavity is indicated in addition to intravenous or intramuscular administration.

PREPARATION OF SOLUTION.—The crystalline penicillin contained in ampoules, 100,000 units per ampoule, is sterile. It is extremely soluble and may be dissolved in sterile, distilled, pyrogen-free water, normal saline solution, or 5 per cent dextrose solution. Additional sterilization is not necessary, and must not be done because heating destroys the potency of penicillin. Occasionally small particles of insoluble material may be present. These can be removed by passing the solution through sterile filter paper or through a filter which is part of an intravenous set.

METHODS OF ADMINISTRATION.—Penicillin is excreted rapidly in the urine and, therefore, it is usually necessary to administer large amounts at frequent intervals to maintain an effective blood level. The most efficient and economical means of accomplishing this result is by continuous intravenous administration at a constant rate or by frequent intramuscular injection (every 3 hours) throughout the 24-hour period.

INDICATIONS FOR USE.—The following are some of the more common conditions which are frequently caused by penicillin-susceptible organisms:

Septic wounds
Septicemia
Cellulitis
Osteomyelitis
Pneumonia
Empyema
Meningitis
Peritonitis
Purulent arthritis
Otitis media
Mastoiditis
Sinusitis
Gonorrhea

Because the sulfonamides are very successful in the treatment of most pyogenic (pus-producing) infections, are available in unlimited quantity, and can be administered orally, it has been the general rule to use these drugs in the primary treatment of the conditions given in the preceding paragraph, reserving penicillin for use in those cases which do not respond or in which there is an idiosyncrasy to sulfonamides.

Experience with penicillin has shown that this agent is more effective than the sulfonamides in the treatment of staphylococcus and gonococcus infections, and as the drug becomes increasingly plentiful, it may be expected to replace the sulfonamides as the drug of choice in conditions caused by these organisms. The response of gonococcus infections to penicillin has been so dramatic that the use of penicillin as the agent of first choice for the treatment of gonorrhea, in persons whose services are urgently needed, has already been authorized.

Penicillin and the sulfonamides are not antagonistic, and in some instances, are actually synergistic (each having an adjuvant effect on the other). Hence, when faced with an acute, fulminating, life-endangering infection, it is often wise to administer both drugs in full dosage.

The optimum total dosage of penicillin in the treatment of gonorrhea has been determined to be 100,000 units. In all other infections, however, there is a wide range of dosage depending upon the severity and duration of the condition and the response to treatment, as well as the many complications which may arise.

Preliminary reports of research in the penicillin therapy of syphilis are favorable. Until final results can be evaluated, however, penicillin is not to be used in the treatment of syphilis in the Navy without specific authorization of the Bureau of Medicine and Surgery.

Penicillin has not been found effective in the treatment of the following conditions:

- Malaria
- Tuberculosis
- Rickettsial diseases (typhus fever, Rocky Mountain spotted fever, etc.)
- Plague
- Tularemia
- Trypanosomiasis
- Fungus infections
- Rheumatic fever
- Bacterial endocarditis

LABORATORY DATA.—When penicillin is administered the following laboratory data should be available:

A. To be obtained on admission and repeated weekly:

1. Complete blood count.
2. Hematocrit.
3. Sedimentation rate.
4. Total serum protein.
5. Blood urea or N. P. N.

B. To be obtained daily:

1. White blood count and differential.
2. Urinalysis.
3. Blood culture.

C. Smear and Culture:

To be obtained before starting penicillin therapy and repeated as indicated by the course of the infection. *The offending organism should be known in all cases.* In mixed infection, such as occurs in wounds, cultures will show disappearance of the susceptible organisms while the non-susceptible organisms may persist. These organisms, if pathogenic, must be attacked by other forms of therapy.

UNTOWARD EFFECTS.—No serious or anaphylactic reactions have occurred following penicillin therapy.

The most common untoward effect observed is a mild burning pain at the site of intramuscular injection. This occurs during the first 48 hours of treatment, but not thereafter.

Other untoward effects such as headache, fever, and abdominal and muscle pains occur rarely.

Thrombophlebitis may occur at the site of continuous intravenous injection and may be prevented by the use of dilute solutions and a daily change of the position of the needle.

CURRENT CLINICAL INVESTIGATION AND RESEARCH.—Prophylaxis of infection in battle wounds with penicillin powder is being studied. The sodium salt of penicillin used in the preparation of solutions for parenteral use and local injection is quite irritant when applied locally as a powder. The calcium salt has been found much less irritant and promises to be of value for direct application to wounds when available in quantity.

Clinical and laboratory studies of penicillin in many diseases and conditions other than those discussed here are being carried on. Preliminary reports from some of these investigations indicate that penicillin may be of value in the treatment of relapsing fever and anthrax.

BLOOD PLASMA AND ALBUMIN.

In the discussion of shock it was stated the essential factor in the development of this important complication of injury or disease is loss of effective circulating blood volume. The significance of loss of blood or other body fluids was mentioned. It is apparent, therefore, that the primary objective in the treatment of shock should be the restoration to normal of the volume of circulating blood. With very few exceptions the best fluid for this purpose is blood. The two major exceptions are in patients with recent burns and with crushing injuries. In these cases hemoconcentration results at first from loss of plasma with retention of the red blood cells, and replacement with plasma is preferred to replacement with whole blood. However, the routine use of whole blood in forward combat areas is often not practicable.

Whole blood deteriorates when stored. When prevented from clotting by the introduction of sodium citrate and kept at refrigerator temperatures under aseptic precautions, it can be safely used after storage for about a week. The addition of dextrose to the citrated blood increases the safe storage period to about 3 weeks. It cannot be reduced in bulk through dehydration.

Plasma (see pp. 29 and 30, *Handbook of the Hospital Corps*) is the fluid which remains after the cells have been removed from whole blood. It can be stored for long periods either in the sterile liquid state or after drying. Water must be added to the dried plasma before it can be used.

Among the many important chemical constituents of plasma are two types of protein (albumin and the various globulins) and the inorganic salt, sodium chloride. When protein food is eaten the complex animal and vegetable proteins are broken down by digestion into amino acids, which are absorbed through the wall of the intestine. Using some of these amino acids as building stones, the liver manufactures the albumin of the plasma.

Plasma albumin has two functions that must be considered here. First, it is important in the nutrition of the various tissues of the body, as the cells draw on it as a source of protein which they can utilize in their metabolism; and second, it tends to draw fluid from the tissues into the blood stream (osmosis) and, therefore, to maintain the blood volume.

Loss of plasma albumin, other factors remaining constant, results in a decrease in blood volume, and when the albumin level is considerably lowered, fluid may be lost from the blood stream to such an extent as to cause swelling of the interstitial tissues (edema). The plasma globulins are protein substances of varying types, and among them are fibrin and prothrombin (important in the clotting of blood) and many of the factors that have to do with immunity to aid defense against infections.

Recent experimental work has shown that sodium is an important element in combating shock. Just how it acts is not known, but two possible actions may be suggested: First, it tends to make the body as a whole retain fluid, and second, by virtue of its behavior as a basic ion it helps to combat the acidosis that tends to develop in shock.

Plasma is, therefore, an ideal blood substitute in the treatment of shock, for it tends to replace fluid lost from the blood stream and (largely by virtue of its albumin) even to draw fluid into the blood stream from the tissues. This latter action is not without danger in patients who are dehydrated, for plasma may produce further *tissue* dehydration and therefore do harm. Consequently, in patients who have lost large amounts of fluids (as those in hot climates, or with diarrhea or vomiting, etc.), it is essential that other fluids, such as saline solution and dextrose solution, be given with the plasma.

Human albumin is provided for use in areas where transportation or storage space is at a premium. It is almost as efficient as plasma in the treatment and prevention of shock. It is obvious from what has been said previously that even greater care must be experienced to combat dehydration when albumin is used in place of plasma. As noted before, it may do more harm than good to a patient whose tissues are dried out.

In addition to its value in combating shock, plasma is used intravenously as a source of protein food in patients who are unable to take food by mouth and in this role is very important.

Most patients suffering from wounds or fractures or burns rapidly develop anemia. This must be combated by transfusions of whole blood after they reach a hospital where blood is available, as plasma and albumin are not efficient substitutes for blood in the treatment of anemia.

The new standard Army and Navy package of dried normal human plasma, when regenerated, represents about 500 cc. of plasma which is the amount obtained from approximately 1,000 cc. of blood and is termed a unit. If shock is severe, the administration of several units may be necessary to overcome it. Additional units may have to be administered before recovery is effected.

As all hospital corpsmen, especially those on combat duty, should be thoroughly familiar with the regeneration of dried blood plasma and its administration, the instructions for use of the "Standard Army and Navy Package of Normal Human Plasma, Dried" as lithographed on each container are reproduced in figure 5.

REACTIONS TO PARENTERAL FLUID ADMINISTRATION.

In the last few years the utilization of the intravenous route for the administration of fluid, blood and blood derivatives, food, and medicines has ceased to be a dramatic gesture in a desperate situation and has become a part of standard medical practice. An illustration of this change in attitude is the widespread use of blood plasma in the prevention and treatment of shock. Hospital corpsmen will often be called upon to administer fluids intravenously, especially when they are on independent duty or are working with medical officers in the treatment of casualties of battle. A sound knowledge of the hazards attendant upon

the introduction of fluids intravenously will lead to a better understanding of the precautions which are essential in their safe employment.

PYROGENIC REACTIONS.—These are by far the most common reactions and may occur after the intravenous administration of any fluid which has been im-

STANDARD ARMY AND NAVY PACKAGE OF NORMAL HUMAN PLASMA, DRIED

INSTRUCTIONS FOR USE

1. Open metal cans with attached keys.
2. Remove plasma and water bottles. Cleanse stoppers with alcohol.
3. Remove cellophane from double-ended needle and remove glass tube from one end of needle.
4. With water bottle in upright position insert uncovered end of double-ended needle through stopper into the water bottle.
5. Remove cellophane and glass tube covering airway needle and insert needle of airway assembly through rubber stopper into the water bottle.
6. Elevate free end of airway assembly to prevent water from wetting cotton filter in airway. CAUTION: If cotton in airway filter becomes wet—remove it.
7. Remove glass tube from other end of double-ended needle. Invert water bottle and insert needle through stopper into plasma bottle. (See diagram A.)
8. Allow water to be drawn into plasma bottle. CAUTION: If vacuum in plasma bottle is lost, apply pressure in water bottle by forcing air into airway tube. If this method fails, remove stoppers and pour water into plasma bottle. Replace stopper on plasma bottle and continue immediately.
9. After water is added, double-ended needle is removed from plasma bottle.
10. Shake plasma bottle until plasma is completely dissolved.
11. Apply metal clamp to the 4-inch piece of rubber tubing on the intravenous set and close it.
12. Remove coverings from short needle attached to intravenous set and insert through stopper of plasma bottle.
13. Withdraw needle of airway assembly from water bottle and insert through stopper into plasma bottle.
14. Invert plasma bottle and suspend it for administration. (See diagram B.)
15. Fix glass end of the airway assembly with the suspension tape above the inverted plasma bottle.
16. Remove cellophane from observation tube and intravenous needle.
17. Attach intravenous needle to tube and remove glass tube from needle.
18. Loosen metal clamp and allow plasma to fill rubber tubing. When tube is filled, and free of air bubbles, tighten metal clamp.
19. Insert needle in vein and regulate flow with screw clamp. If patient is to receive additional plasma, restore second bottle as outlined. Close regulating clamp as soon as first bottle is empty, but before air enters tube. Pull out needles from first bottle and insert in second bottle. Elevate end of airway and fix it in place with the suspension tape.

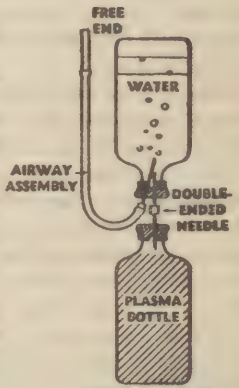

DIAGRAM A
RESTORATION OF THE DRIED PLASMA

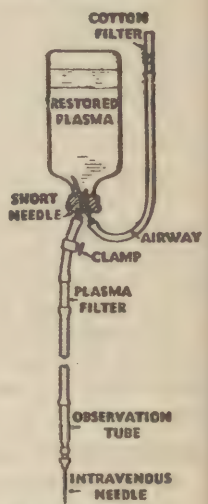

DIAGRAM B

FIGURE 5.—Instructions for use of standard Army and Navy Package of normal human plasma, dried.

properly prepared or administered with improperly prepared apparatus. *Pyrogens*, strictly speaking, are substances which will provoke a febrile reaction after intravenous administration, and are usually the product of bacterial growth

and disintegration of bacterial bodies. Poorly prepared or preserved distilled water, water from contaminated glassware, and practically all tap water contain pyrogens. They cannot be removed or rendered harmless by sterilization by heat, and they will pass through sterilizing filters.

The only effective means of removing pyrogens from water is proper distillation. If distilled water contains pyrogens, their presence is usually due to one of three causes: First, the still or the container used to collect the distillate is contaminated; second, faulty construction of the still allows droplets of water carrying pyrogens with them to be carried over with the current of steam; and third, perfectly distilled water may be allowed to stand under conditions that permit contamination by bacteria. It is therefore desirable to start with as good a water as possible and to operate the still at a rate about half that of the rated capacity. No distilled water should be used more than 3 to 4 hours after distillation unless it has been sterilized in a sealed container.

As human blood, plasma, and serum are relatively good media for bacterial growth, every precaution should be taken to prevent their contamination by bacteria. These precautions include asepsis in the collection of blood, and the preparation of plasma and serum by the closed method. Refrigeration will retard but not stop bacterial growth.

Aside from the pyrogens contained in the fluid itself, there is another and perhaps even more common source of pyrogenic reactions. This is the glassware and rubber tubing used to prepare and administer the material. Dirt and dust, the excess of sulfur on new compound rubber tubing, and allowing the apparatus to stand wet for many hours are important factors. The remedies are: (1) Avoidance of contamination of the fluids remaining unused after administration; (2) proper cleaning of glassware and other apparatus followed by rapid drying or sterilization; and (3) not storing distilled water over three hours after preparation unless sterilized.

In patients with fever, especially if of the septic type, the intravenous administration of fluids, particularly whole blood, often causes a temperature rise. It is desirable in these cases, whenever possible, to administer intravenous fluids at a time when the temperature is at its expected low, usually in the morning.

Embolic Reactions.—Whole blood should always be filtered immediately before administration. This is particularly important for blood preserved at refrigerator temperature for a period of time, because of the rapid and progressive formation of numerous fine, soft flocculi. Plasma and serum should always be filtered at the time of preparation, preferably at the time of pooling. Flocculation of plasma may be entirely avoided by preserving plasma in either a frozen or dry state. Effective filtration of flocculi, particularly threadlike precipitates of fibrinogen, is easily accomplished by the use of four layers of 40-mesh gauze or equivalent material. The use of standard 200-mesh stainless steel gauze is equally satisfactory.

Allergic Reactions.—These are usually attributed to substances of alimentary origin, to which the recipient is sensitive, contained in the whole blood, plasma, or serum. They consist of localized urticaria or, less frequently, generalized urticaria with a rise of temperature and other angioneurotic symptoms. One way to reduce allergic reactions is to insist that blood be obtained from the donor when in a fasting condition.

Heated Blood or Plasma.—The administration of even large quantities of cool fluids intravenously does not cause reactions. In view of the fact that severe reactions may follow administration of excessively heated whole blood, plasma, or serum, it is desirable to eliminate entirely the practice of warming transfusion fluids prior to administration.

HEMOLYTIC REACTIONS.—Essential preventive measures are careful blood grouping of the recipient and the donor. The preparation for a blood transfusion must be done by a well-trained person. The sera used for grouping must be of high potency, and should be checked at regular intervals against cells of known groups. the anti-A serum must be capable of agglutinating the subgroups A and AB. All tests should be checked microscopically as well as macroscopically.

From all the experimental work done to date, it seems justifiable to go on the assumption that serum, plasma, or group O blood with an unusually high isoagglutinin titre may cause hemolysis of the susceptible recipient's cells in some instances. These reactions are very rare and can certainly be readily avoided by pooling the blood or blood derivative.

A reaction to incompatible blood usually starts during or shortly after the transfusion. A chill usually occurs, often followed by fever, nausea, vomiting, plain in the back, and a sense of constriction in the chest. There may be pain over the bladder and an urge to defecate. Later, reddish-brown urine may be passed, and this may be followed by the development of jaundice which usually reaches its peak within 24 hours. Examination of the urine reveals the presence of albumin, hematin casts, hemoglobin, and red cells. The mechanism of these changes is the hemolysis of the donor cells by the antigens in the patient's serum. Hemoglobin is liberated from the destroyed red blood cells and excreted in the urine. In the uriniferous tubules of the kidney the acid urine transforms this hemoglobin to acid hematin which is insoluble and tends to form casts obstructing the flow of urine. The patient may survive a mild transfusion reaction, the flow of urine being resumed and normal recovery taking place. On the other hand, if the number of tubules so obstructed is sufficiently great, the condition will progress in the direction of uremia and death.

The amount of blood administered seems to bear some relation to the result, an argument for slowly and cautiously giving transfusions where hemoglobin reactions are feared and for immediately stopping any transfusion at the first symptom or sign of unfavorable reaction. Once a severe reaction has occurred, treatment should consist of (1) maintaining an adequate though not excessive fluid intake, and (2) giving enough bicarbonate of soda by mouth (4 Gm. every 4 hours) to alkalinize the urine, thereby limiting the formation of acid hematin.

SPEED OF ADMINISTRATION is an important element in safety. In general, a rate of 20 cc. per minute is ordinarily perfectly safe and well tolerated. In patients in severe shock it is wise to administer the initial unit or two of plasma at a much faster rate. As much as 500 cc. can be administered in a period of 10 minutes. Beyond this quantity it is advisable to reduce the rate of administration. Whole blood should be administered more slowly because of its high viscosity. With increased speed the concentration of pyrogens may at any time rise sufficiently to cause severe reactions. The quantitative relationship between the severity of hemolytic reactions and the amount of whole blood administered makes slow injection desirable when such reactions may be anticipated. When not dealing with an emergency, therefore, the fluids should be administered at the slowest rate compatible with good results, not over 20 cc. a minute.

BENZEDRINE (Amphetamine).

This substance is a synthetically prepared racemic (optically inactive) mixture of bases that has the formula $C_6H_5CH_2CHNH_2CH_3$, is structually related to both ephedrine and epinephrine, and possesses the fundamental grouping responsible for vasoconstrictive properties. Benzedrine occurs as a colorless, mobile liquid that boils at 200° to 203° C. with slight decomposition, has a strong

basic odor and burning taste, and is soluble in ether and alcohol and slightly so in water.

Benzedrinae Sulfas, Benzedrine Sulfate, Amphetamine Sulfate, (Alpha methylphenethylamine; Racemic desoxy-norephedrine sulfate; Racemic benzylmethyl carbinamine sulfate), $[C_6H_5.CH_2CH(NH_2).CH_3]_2.H_2SO_4$, N. N. R.—This compound is regarded as the most satisfactory of a group of analeptic (restorative; giving strength) drugs which can enable persons to continue, for a time, to perform their duties efficiently when normally their performance of duty would be seriously impaired because of extreme fatigue or because they would be unable to stay awake.

PROPERTIES: Benzedrine sulfate occurs as a white, odorless powder, is freely soluble in water, slightly soluble in alcohol, and insoluble in ether, and melts at over 300° C. Its aqueous solution is neutral to litmus.

ACTION: In states of severe or extreme fatigue this drug, in suitable doses, temporarily removes the desire for rest and sleep and produces feelings of self-confidence and well-being. It also produces improvement in the performance of skilled acts during states of severe fatigue.

In moderate doses benzedrine sulfate does not produce serious adverse effects. Approximately 10 per cent of persons notice such symptoms as palpitation and feelings of tension or uneasiness after a moderate dose such as 10 mg. taken when not fatigued. These symptoms are less frequent when the drug is taken during severe fatigue. Following 10 mg. there is some increase of heart rate, and systolic and diastolic blood pressures, but these are too small to be regarded as important in healthy subjects.

This drug should not be administered to the severely wounded because it may increase hemorrhage. It produces some increase in sweating and in thirst, but it is not regarded as being contraindicated in extreme conditions of humidity, heat, or cold. In excessive or unduly prolonged usage unfavorable symptoms are common. Included among such unfavorable symptoms are headache, anorexia, abdominal cramps, constipation, dizziness, irregular heart action with tachycardia and palpitation, and numerous adverse mental reactions. There have also been reported instances of euphoria with excitement, overconfidence, impaired judgment and hallucinations following excessive dosage or continued use over too long a period. With continued over-use there have been instances of vasomotor collapse. To avoid the possibility of serious adverse reactions the dosage prescribed in the paragraph beginning "Dosage" must be strictly observed.

Benzedrine sulfate is not known to cause addiction in the sense of a craving for the drug. There are no withdrawal symptoms except a desire for rest and sleep. It is, however, possible to form a habit of depending on the drug to overcome moderate feelings of fatigue.

The need for sleep and rest is postponed, but not eliminated, by use of this drug. With continued use increasing doses are necessary in order to stay awake and adverse reactions become more common. It should not be employed in situations or emergencies which may continue more than 24 hours after the appearance of severe fatigue. It does not improve intellectual or psychomotor function when taken while in a normal state and there is no satisfactory evidence that it reduces or prevents seasickness or airsickness.

USES: Because benzedrine sulfate is regarded as the most satisfactory of a group of stimulants which have been used in certain tactical and emergency situations in the present war the following excerpts from a letter of the Bureau of Medicine and Surgery addressed to all ships and stations relative to its use are quoted:

"The operational use of benzedrine shall be limited to specific tactical or emergency situations and decision as to such use shall be arrived at by consultation between commanding and medical officers. Medical officers will be responsible for the custody of supplies and the supervision of administration and dosage. Operations in combat areas may, however, give rise to situations in which the use of benzedrine would be advantageous at times and places when a medical officer is not available. Such conditions may be met by placing the necessary supplies under the custody and supervision of unit commanders.

"The following are examples of tactical and emergency situations in which the use of benzedrine may be indicated:

"(*a*) Tactical operations in which the highest possible efficiency is necessary for a total of not over 24 hours beyond the onset of severe fatigue. Such tactical plans must include a rest period of at least 12 hours following the prolonged activity. Tactical situations fulfilling these requirements may occur in naval and Marine forces during raids or the establishment of beachheads and possibly also in some operations at sea. In such operations the time of administration and dosage of benzedrine should be written into the tactical orders after consultation with medical officers and the drug will then be supplied to unit commanders in appropriate quantities.

"(*b*) Flying personnel may experience severe fatigue during the return from prolonged patrol or bombing missions. Under such circumstances pilots and others have shown dangerous impairment of skill or inability to stay awake. When such conditions are expected medical officers may issue benzedrine to flying personnel with instructions as to proper dosage.

"For operational situations in which the use of benzedrine may be justified after consultation between commanding and medical officers, the use of the drug shall be governed by the following conditions:

"(*a*) Not to be employed in situations or emergencies which may continue more than 24 hours after the appearance of severe fatigue.

"(*b*) Officers and men in key positions in which good judgment and the making of decisions outweighs the allaying of fatigue, not over 5 mg., single dose, repeated no more than 3 times at intervals of 6 to 8 hours.

"(*c*) For allaying sleepiness and fatigue, all other men, not over 10 mg., single dose, repeated no more than 3 times at intervals of 6 to 8 hours."

DOSAGE: The effects of benzedrine appear in about 1 hour after ingestion and continue for 6 to 8 hours. Single doses should not exceed 10 mg. Such doses should not be repeated more than 3 times at intervals of 6 to 8 hours, after which the need for sleep and rest is imperative. A total of 30 mg. should not be exceeded in any 1 week. For officers and men in key positions in which good judgment and the making of decisions outweighs the allaying of fatigue, not over 5 mg., single dose, repeated no more than 3 times at intervals of 6 to 8 hours.

It is essential that all persons who may be responsible for the administration of benzedrine to themselves or others be thoroughly familiar with the proper dosage and limitations of usefullness of this drug, especially as excessive or unduly prolonged use of it can produce unfavorable effects.

Benzedrine sulfate is available for issue and may be procured from Naval Medical Supply Depots and Naval Medical Storehouses under the following designation:

Stock No.	*Status*	*Item*	*Unit*
S1-3991	T	Racemic Amphetamine Sulfate, waxed paper package containing 6 tablets of 5 mg.	One (1)

Supplies of benzedrine should be kept under lock and key and issued only under the immediate supervision of responsible officers who are familiar with its characteristics.

HYGIENE AND SANITATION

Scabies.

For the routine treatment of scabies, *benzyl benzoate* is recommended to supersede sulfur. The formulas of two satisfactory preparations containing benzyl benzoate are given:

1.

Benzyl benzoate	25.0 Gm.
Stearic acid	2.0 Gm.
Triethanolamine	0.5 cc.
Water to make	100.0 cc.

Mix and make emulsion.

2.

Benzyl benzoate	25.0 Gm.
Medicinal soft soap (green soap)	35.0 Gm.
Alcohol (95 percent)	40.0 cc.

Mix.

Before using either of the benzyl benzoate preparations the patient should be bathed with soap and water and dried. Then the preparation should be applied over the entire body, from neck to soles, using a paint brush and employing about 2 ounces for a treatment. The application should be repeated the second day and the preparation removed by bathing on the third day.

Whenever a case of scabies is reported all men in the unit should be inspected for the presence of the condition.

Fungus Infections of the Feet.

The most frequent locations for fungus infections of the feet are between the third and fourth and the fourth and fifth toes, and on the instep. The disease may manifest itself on the one hand as only a slight swelling, or on the other, as deep-seated vesicles. When such vesicles break, they may form excoriated lesions which may become painful and tender or they may form the simple cracks so frequently seen between the toes. The lesions may also become secondarily infected with pyogenic organisms, forming pustules locally, or spreading along the lymphatics to produce a lymphangitis. Lymphangitis can be recognized by the presence of red streaks running up the leg, and by the presence of enlarged lymph nodes in the groin. Secondary pyogenic infections may spread also to the subcutaneous tissues to produce a cellulitis, most often of the dorsum of the foot, and characterized by tenderness, swelling, redness, and increase in the local temperature.

It is often possible to make a clinical diagnosis of fungus infection of the feet simply from the appearance of the scales, vesicles, and pustules around the webs between the last three toes and under the instep. However, definite proof of the diagnosis can be determined only when a capable bacteriologist finds the causative organism in smears or cultures.

A large percentage of the adult population has or has had fungus infection of the feet. Most cases are mild, but where conditions characterized by excessive warmth and moisture exist, the infection may develop to an extent where it becomes painful and disagreeable, and, especially when secondary infection

develops, may be disabling. Treatment, where possible, should be directed toward controlling the disease in its mild form and preventing infection and further complication. Proper foot hygiene is of prime importance and should include frequent washing and thorough drying of the feet especially between the toes, and putting on clean socks at least daily. Careful washing, rinsing, and drying of the feet tend to be neglected when shower baths are used because of the difficulty in attending to this where there is no place to sit down. Further effort should be made to keep the feet dry, especially between the toes, by the use of any one of the available medicated dusting powders. Ointments should not be used in the treatment of fungus infections of the feet where one is wearing socks and shoes, nor should it ever be used in tropical climates. If an ointment is desirable, ½-strength Compound Ointment of Benzoic Acid, N. F., (Whitfield's ointment) is one of the best. It should be applied, however, only on retiring.

When pustules appear they should be opened with aseptic technique and wet dressings applied until the infection is under control. Boric acid dressings are satisfactory. Soaking the feet in potassium permanganate solution may be of value. In certain cases X-ray therapy may be helpful, but should not be attempted by anyone not experienced in its use. Many fungicides are available in the form of powders, lotions, ointments, etc. These may, however, contain strong medications capable of producing a chemical dermatitis which may cause more trouble than the disease for the treatment of which they were intended.

Fungus Infections of the External Auditory Canal.

These infections are very common in the tropics where conditions of excessive heat and moisture favor their development.

The fungi infecting the external auditory canal belong to two families, the *Mucoraceae* and *Aspergillaceae*. There are several members of the latter family which are pathogenic in man, the most common being *Aspergillus niger*, *flavus*, and *fumigatus*.

They may attack only the epidermis or the deeper structures. Occasionally the ear drum itself or the middle ear may be involved.

The symptoms depend largely on the severity of the infection. In some instances there are no symptoms other than itching, and the presence of scales and fissures at the external auditory meatus. The latter condition is usually aggravated by attempts on the part of the patient to relieve the itching by scratching with the fingers or other objects. Within the external canal there is usually a thick grayish discharge, which may have a fetid odor. The underlying skin may be inflamed, and there may be evidence of desquamation of the epithelium. The patient may complain of deafness. Furunculosis may be a complication.

This type of infection may extend over several weeks and recurrences are frequent. The diagnosis is made by finding the organisms in the smear of the exudate from the canal.

Dermatitic conditions of the external auditory canal of other than fungus origin can present the same clinical picture. Other conditions to be differentiated from a fungus infection include: Suppurative otitis media, impacted cerumen which has undergone decomposition, and bacterial infections. *The Pseudomonas aeruginosa* and other bacteria may cause infections of the ear clinically difficult to distinguish from a fungus infection. Many times the condition is obscured by superimposed streptococcus or staphylococcus infection.

In the prevention of fungus infection of the ears in the tropics, keeping water out of the ear canal is important.

Treatment of fungus infections of the ear offers many problems; it can be said that there is no drug or mixture of drugs which is a cure. What will

effect relief in one patient may not necessarily benefit all patients. The treatment of fungus infections of the ear is similar to the treatment of external otitis in general.

Watery solutions generally are contraindicated in that they tend to cause a greater degree of swelling of the inflamed skin. Treatment is directed toward the drying up of the discharge and bringing about a scaling or flaking off (exfoliation) of the infected skin.

A 1 to 3 per cent alcoholic solution of salicylic acid is commonly used in the form of drops instilled into the external canal 2 to 3 times a day. A 3 to 5 per cent solution of aluminum acetate placed in the canal on a gauze pack and kept moist with the solution for 24-hour periods is often effective. In the case of both of these solutions, desquamation of the epithelium results and the epithelial debris may be removed by gentle swabbing.

A solution of 2 per cent thymol in 70 to 95 per cent alcohol or of 2 per cent thymol in cresatin are effective fungicides. Dusting powders consisting of thymol, boric acid and iodine, or the sulfonamides are very often effective, especially in those cases where the bacterial infection predominates. Suberythemal doses of X-ray in conjunction with local therapy have given good results.

The disease tends to recur and the patient should be advised to seek treatment whenever symptoms are present, to keep the ears dry, and to avoid swimming.

The Importance of Dust and Blankets in the Spread of Respiratory Infections.

The conditions of crowding incident to military life are particularly conducive to the spread of communicable diseases. This is true especially of infections of the respiratory tract. Many people who are not ill as well as those with low-grade upper respiratory tract infection may harbor in their noses and throats streptococci, pneumococci, meningococci, or the viruses of the common cold, influenza, or atypical pneumonia.

Such persons cough and sneeze into the air moisture-droplets containing large numbers of bacteria. The larger droplets tend to fall to the floor or to the blankets. Some of the smaller droplets may lose their moisture before falling to the floor, leaving the bacteria freely floating in the air. Thus, in the blankets and in the dust of barracks and in hospital wards may be countless numbers of bacteria capable of producing disease.

Any activity which tends to shake blankets (as bed-making or sick call) or to stir up dust (as dry sweeping or the traffic incident to meal-times) causes these bacteria to be thrown into the air in large numbers.

It becomes apparent that dry sweeping should, wherever practicable, be avoided. The use of light floor oils has been found to have a valuable effect in keeping dust particles and their attached bacteria from getting into the air. Other helpful methods are using the vacuum cleaner, using an oiled mop, or sweeping with oiled sawdust. The application of a floor oil has been found to lower significantly the bacterial content of the air of a ward for more than a week.

Blankets should, when possible, be thoroughly shaken out-of-doors, aired and exposed to the sun, and, whenever practicable, sterilized. It has been found that bacterial contamination of the air from blankets may be minimized by impregnating blankets with a solution of mineral oil in a solvent such as turpentine. This method is still in the experimental stage but offers considerable promise.

Much experimental work has been done in recent years on sterilization of air by means of aerosols, such as propylene glycol, or of radiation by ultraviolet light. Both ultraviolet light and the glycols will destroy bacteria in the air within a reasonable time. However, under peak conditions, such as sweeping and bed-making, they do not produce significant reduction in bacterial levels.

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A mineral oil suitable for use on floors is the one listed in the General Schedule of Supplies as item No. 14–O–865. Federal Specification P–O–361 requires that this oil be straight-run petroleum distillate, either with no objectionable odor or prepared with cedar or pine oil. It must be clear, with a viscosity of not less than 70 nor more than 110 seconds (Saybolt Universal) at 100° F. The flash point must not be less than 300° F. (open cup). The color must not be darker than 3 N. P. A. (lemon pale) (ASTM #3). The pour point must not be more than 30° F.

Demineralization of Sea Water.

During 1944, kits for the chemical demineralization (desalinization) of sea water will be added to the equipment of some Navy rafts. The first kits to be procured employ the so-called Permutit Process. These kits consist of several briquets of the active chemical, each sufficient to produce about one pint of drinking water, and in addition, a plastic bag. In this bag the reaction between the sea water and the chemical is carried out. The treated water is sucked out through a filter in the bottom of the bag by the survivor. Detailed directions for use are furnished with each kit.

The active chemical is known as "silver zeolite." (Zeolite is the name of a family of minerals consisting of hydrous silicates of aluminum with alkalis or alkaline earths or both. Certain artificial zeolites are used in a process for softening water.) The reaction with the sodium chloride in sea water may be outlined as follows:

$$\text{Ag zeolite} + \text{NaCl} \rightarrow \text{AgCl}\downarrow + \text{Na zeolite}\downarrow$$

The precipitates of silver chloride and sodium zeolite are removed by filtration. Magnesium, also present in sea water, is removed during the treatment. The process reduces the solids in the water from the 3.0 to 3.5 per cent originally present in sea water to about 0.4 to 0.6 per cent. The solid remaining is largely sodium chloride and sodium sulfate, in concentration just sufficient to impart a slightly salty taste to the finished water. These salts do no harm, as in such small amounts they are readily excreted by the kidneys.

Insect Control.

LICE.—The body louse (*Pediculus humanus* var. *corporis*, sometimes called *Pediculus vestimenti*) transmits the epidemic (European) form of typhus fever. Also, by causing severe itching and consequent loss of sleep, it seriously undermines morale. Scratching leads to the development of secondary infections.

Louse-control discipline and good personal hygiene are of great importance in the prevention of louse infestation. (See p. 449, *Handbook of the Hospital Corps.*) Frequent talks to the personnel regarding the dangers from lice and the methods of keeping themselves rid of them are of value. Ample laundering and bath facilities should be provided where possible, and frequent inspections should be made of personnel and clothing to detect the presence of lice, special attention being given to the seams of the innermost clothing. Running a heated flatiron over the seams will destroy ova.

INSECTICIDE POWDER.—A new insecticide powder has been developed which is highly effective in louse control. This powder is carried in the Supply Catalog of the Medical Department, U. S. Navy as Item No. S13–451. The active principle is dichloro-diphenyl-trichloroethane, or D. D. T. Clothes may be dusted with it whether they are on the person or not.

A plunger-type hand duster or a compressed-air powder duster is satisfactory for application of the powder to clothes which it is not practicable to remove. The powder should be blown under the innermost layers of the clothing, care

being taken that every part is reached and that the seams receive special attention. One ounce of the powder is ample for this procedure. The application need be made only every two to four weeks, provided the individual does not change the clothing or bathe, but it must be repeated after laundering the clothes.

Dusting by hand requires a little over an ounce of the powder. It should be rubbed into the seams, especially the inner folds of the seams. When properly applied by spray or by hand, all lice will be killed within 48 hours.

This powder (or a louse spray liquid containing D. D. T.) applied to the hairy parts of the body will protect against and exterminate all types of lice and nits. In addition, it can be used for other clothing and bedding. It is effective against ants, fleas, house flies, bed bugs, and certain biting, disease-carrying insects.

Experiments being conducted at the present time indicate the possibility of impregnating underwear and other clothing with a 1 per cent emulsion of D. D. T. The results to date make it appear that underwear so impregnated remains louse-free for about 8 weeks despite 10 washings and frequent exposure to lice. Adoption of this method of using D. D. T. will have to await the results of further field trials.

D. D. T. has an advantage over steam and methyl-bromide fumigation in that it has persisting prophylactic value against reinfestation and is simpler to use. Although nonirritating and nontoxic when used externally, this substance is poisonous when ingested in sufficient quantity. Proper precautions should be taken to avoid its getting into food.

Methyl Bromide as a Fumigant for Delousing Clothing.—Although extensively used for the fumigation of living plants and of various types of foodstuffs, methyl bromide has only recently been used for the delousing of clothing and bedding. The Army has used it successfully for the destruction of bed bugs in barracks.

Methyl bromide is a colorless, odorless, volatile liquid with a boiling point of 40.1° F., and a specific gravity of 1.732. In the gaseous state it is approximately three and one-half times as heavy as air.

Methyl bromide is definitely toxic. Experimentally, long-continued exposure at low concentrations induces paralysis which usually disappears if the animal is promptly removed from the presence of the gas. Long-continued exposure to stronger concentrations produces acute lung irritation which often passes into typical confluent broncho-pneumonia.

Individual bag fumigation is recommended only for emergency use when other means are not available or practical. The bag used for this purpose is a plasticized bag which will hold about 25 pounds of clothing. On the inside is a pocket for holding the ampoule of methyl bromide. One 20 cc. ampoule of methyl bromide per single bag operation is required for this method. The clothing and blankets (leather goods included) are placed loosely in the bag; a glass ampoule of methyl bromide is placed in the inner pocket; the bag is securely closed; the ampoule broken, and the bag laid on its side for a period of 45 minutes. Then it is opened and the clothes are dumped out, shaken, and left in the open for 5 minutes after which they can be worn again. In view of the likelihood of multiple leaks in the bags, and the large amounts of methyl bromide released when the bags are opened, fumigation by this method must always be carried out in the open.

The advantage of methyl bromide over heat is its application to woolens and leather and rubber goods without damage. It kills lice and their eggs in 30 minutes when used in the manner described.

PYRETHRUM BOMB.—The pyrethrum bomb contains in addition to pyrethrum, Freon gas under pressure. When the contents are allowed to escape, the pyrethrum is expelled in a very fine mist. This device has proved very effective in enclosed spaces and even in semienclosed spaces and foxholes. While very efficient against certain biting, disease-carrying insects, it is not efficient enough against flies to justify its use in combating them.

For some years pyrethrum has been the most satisfactory inseticide. Because of the present shortage of pyrethrum, its use has had to be restricted largely to the pyrethrum-Freon bomb.

D. D. T. also is an efficient insecticide. While the speed with which it kills certain biting, disease-carrying and other insects is not as great as that of pyrethrum, it has the advantage of greater persistence, that is, it will continue to act, wherever applied, for a much longer time. Production of D. D. T. is progressing rapidly. At the time of writing this section, it is already in use as a delousing agent. However, it appears that before long production will reach a degree that will permit its wide use as a general insecticide.

INSECT REPELLENTS.—New insect repellents have been developed and are now in use. The most satisfactory of these are: Dimethyl phthalate, indalone, and Rutgers 612.

One standard Navy repellent mixture contains all of these substances and another contains two of them. These repellents, when applied to the skin, will protect for from 1 to 5 hours against the bites of certain biting, disease-carrying insects, sand flies, biting flies, gnats, mites, flies, and ticks. When applied to clothing, the effect may last as long as a week if the clothing is not laundered.

GENITOURINARY AND VENEREAL DISEASES

PROPHYLAXIS AND TREATMENT OF GONORRHEA

Prophylaxis.

In 1910, the gonorrhea admission rate for the U. S. Navy was 103 per 1,000. The latest data available show the rate for 1942 to be 26.03 per 1,000. In 1910, gonorrhea was responsible for 52.86 per cent of all the venereal diseases, in 1942 it was responsible for 81.61 per cent of the total venereal diseases admitted in the U. S. Navy. Although the admission rate has dropped four-fold, gonorrhea has become today by far the most common and the most important venereal disease.

Like any disease, gonorrhea can be prevented only by avoiding contact with the gonococcus. Unlike many diseases, except in the occasional cases of conjunctival infection, direct contact is necessary. It must be admitted that accidental transmission of the gonococci to the urethra is within the realm of possibility but not of probability. It is correct to assume that sexual intercourse preceded every case of gonococcus infection of the urethra in the male. No exposure rules out the possibility of gonorrhea. Also, exposure followed by proper precautions almost always means no infection. There are, however, two basic protective measures: (*1*) Continence, or avoiding exposure; and (*2*) prophylaxis carried out correctly.

Continence, while treated lightly by some, is by far the best preventive; no exposure, no infection, no worries.

For those unable to control their desires, and perfectly normal desires they are, prophylaxis is always available, and if properly used will give 98 to 100 per cent protection. Through education both of these preventives are now widely known and hence the marked fall in the gonorrhea rates. Continence is the better, but if exposure takes place, then prophylaxis is the common-sense way of looking at the problem.

Prophylaxes are of two types: (*1*) Mechanical (the condom, rubber, sheath, fishskin); and (*2*) chemical (self-administered, and supervised).

Mechanical.—Of the two, mechanical prophylaxis is still the better, the safer. Like an insurance policy, the very small premium cost pays big dividends in the protection it renders. The cheap brands sold at places where prices are low are often of inferior makes, or are discards or rejects. Those handled by naval activities meet the specifications laid down by the Pure Foods and Drug Administration. The condom should be applied carefully, leaving adequate space at the end, and should be removed just as carefully. It is entirely possible that gonorrhea can be contracted in the so-called "playing around" period before and sometimes after actual intercourse takes place. The proper use of the condom, unless it breaks, gives 100 per cent protection against gonorrhea, and it is a highly efficient prophylaxis against the other venereal diseases.

Chemical.—Any chemical prophylaxis taken on the spot is better than one taken later on. The Navy Prophylactic Tube is free and should be made avail-

able to all men with even a thought of exposure in their minds. The content of the present tube is prepared according to the following formula:

	Parts
A. White petrolatum	98.0
Oxyquinoline benzoate	1.0
d-Sorbitol	1.0
Mix to make ointment base.	
B. Of the ointment base	67.0
Mild mercurous chloride (calomel)	33.0
Mix and make ointment.	

When properly used immediately after exposure (and it should be used even if a condom has been worn), it affords 98 per cent protection against all venereal diseases. The technique for use has not changed and is given in detail on p. 513 in the *Handbook of the Hospital Corps.*

The U. S. Navy maintains in all ships and stations and in many cities, facilities for administering venereal prophylaxes. This procedure also is described in detail on p. 513 in the *Handbook of the Hospital Corps.* The advantage of these station-prophylaxes is supervision which results in the use of correct technique. The disadvantages are the inconvenience due to distance and often, therefore, the inability to render prophylaxis within the required time.

In recent years the sulfonamides have been used extensively for prophylaxis. The Bureau of Medicine and Surgery has not authorized the adoption of this procedure for reasons given later.

Sulfathiazole and sulfadiazine have been the drugs of choice and, except in isolated cases, have been used after exposure. When given in 2 Gm. doses immediately upon reporting by the exposed man, they have decreased the incidence of gonorrhea. At the present time 30 to 40 per cent of all gonorrhea cases are sulfonamide-resistant. It is a logical deduction, therefore, that sulfonamide prophylaxis will fail to protect against gonorrhea in a like percentage of the cases. Any prophylaxis only 60 to 70 per cent effective is not to be endorsed. Idiosyncrasy, or possibly sensitivity, to these drugs is another factor indicating the inadvisability of using the sulfonamides routinely. It is definitely known also that while protecting against gonorrhea in the above percentage of exposures, the sulfonamides are worthless as prophylaxis against syphilis.

Considerable research is being conducted constantly, and the Bureau of Medicine and Surgery is closely following each development. Adoption of any results of these research studies is dependent upon proof that the new method will be superior to those now in use.

Treatment.

The present method of treatment of gonorrhea, after diagnosis has been conclusively established, utilizes sulfonamide therapy. Although sulfathiazole is the drug of choice, sulfadiazine may be used. Sulfathiazole will frequently be successful where other sulfonamides have failed. It is rare, however, to accomplish much through re-treatment with another sulfonamide in those cases which have previously failed to respond to sulfathiazole. In all treatment schedules of gonorrhea, it has been considered essential that the patient drink large amounts of water. This serves as an aid in the mechanical flushing of the urethra. With the sulfonamide therapy it is even more important that this increased fluid intake be maintained in order to prevent precipitation of the sulfonamide crystals in the urinary tract. As most all of the sulfonamide reactions occur subsequent to a 5-day course of therapy, it is not necessary

to perform preliminary blood counts or urinalyses except when definite reactions occur in those cases where re-treatment is indicated.

The accepted form of therapy is as follows: Sulfathiazole 1 Gm. (2 tablets) at 0800, 1200, 1600, and 2000 daily for 5 successive days for a total of 20 Gm.

Normally the patient can be treated as an ambulatory case. Aviation personnel and other patients requiring full control of their auditory, visual, and equilibrium functions should not be allowed to resume their original duties before 5 days after being taken off the sulfonamide. The question of duty-status treatment or hospitalization depends upon the local situation as regards the patient's duties and the theater of operations. Hospitalization generally is not indicated and duty-status treatment avoids loss of time and pay, and decreases the aggregate number of sick days. The addition of sodium bicarbonate 1 Gm. (or 15 grains) to each dose of the sulfonamide aids in preventing precipitation of the sulfonamide crystals in the pelves of the kidneys, but otherwise, in the opinion of most, does little toward preventing reactions to the sulfonamides. While under sulfonamide therapy the patient should be seen at the medication times listed and observed for any untoward reactions such as nausea, vomiting, dizziness, or skin rash. These symptoms normally disappear upon discontinuing the drug. Obviously the drug should be stopped if and when such warnings occur.

Re-Treatment.

As previously stated and somewhat dependent upon locality, a certain percentage of the cases will fail to respond to this treatment either wholly or in part. After a lapse of 3 to 5 days the patient should be re-treated with exactly the same schedule as already outlined. When a drug other than sulfathiazole was used in the original treatment, it is well to re-treat with sulfathiazole as the chance of a favorable result is somewhat increased. The patient should be questioned as to past reactions, if any. Before and during the second course the patient should be closely checked, including complete blood count and urinalysis. Reactions are more prone to occur with re-treatment.

The percentage of successes of this treatment will vary from 60 to 70. In many series it will be higher. Little, if any, advantage is gained by re-treating with sulfonamides after two complete courses have been given. The cases that fail, as signified by persistent urethral discharge and the demonstration of the gonococci, should be hospitalized. If this is impracticable, the patient should be treated with gentle injections of 7 cc. of 1 per cent protargol or 10 per cent argyrol (silvol) into the anterior urethra morning and night. This should be continued until the patient is cured or can be hospitalized for more effective treatment. Err on the side of conservatism rather than radicalism. Instrumentation is rarely indicated.

Caution.—The greatest danger of gonorrhea is to the patient. Except in gross negligence in contaminating towels or hands, the infection will not be transmitted to the eyes of others resulting in gonococcus conjunctivitis. The patient, however, is to be warned of this danger both to himself and others, and advised as to the necessity of personal cleanliness in preventing it. The complications of gonorrhea that may arise are listed on pages 498 to 503 in the *Handbook of the Hospital Corps.* These occur much less frequently under the present-day methods of treatment. The basic treatment for each is given in the *Handbook.* Almost all complications will respond favorably to bed rest, and conservative and gentle treatment, plus sulfonamide therapy as outlined for the acute uncomplicated cases.

Chronic gonorrhea.—This also is less common than formerly. Many will

respond to a second course of sulfathiazole. If this fails, hospitalization is indicated.

Penicillin, up to the present, appears to be the drug for which all have been searching. Present data are extremely favorable. The possibility that there may result penicillin-resistant strains must be remembered. However, conclusions so far drawn indicate that at least 97 per cent of the cases treated with penicillin (largely sulfonamide-resistant cases) are cured in 24 to 48 hours. By retreating those failing to obtain complete cure, the percentage of successes has been raised to 99.2 per cent. The word "cure" is used provisionally as it refers to penicillin therapy of gonorrhea.

Briefly, the mode of treatment with penicillin is as follows: Ten thousand units in 2 cc. normal saline solution are injected intramuscularly every 3 hours for 10 doses. This 100,000 total units will give cures in approximately 99 per cent of the cases in which it is used. Smaller total-unit doses give a slightly lower percentage of successes. In one large series of cases, 50,000 units total per case resulted in 85 per cent cures. No reactions of note have been reported. Penicillin obviously has been used for gonorrhea therapy only as the war needs permitted. Penicillin has recently been made available on Supply-Depot requisition, but it should be emphasized that the need for penicillin must be justified in an accompanying letter to the Material Division, U. S. Naval Medical Supply Depot, Brooklyn, N. Y., Mare Island, Calif., or Pearl Harbor, T. H.

Penicillin therapy of gonorrhea is no longer entirely restricted to sulfonamide-resistant cases and where the penicillin available is not required for the treatment of grave infections, it may be used in the primary treatment of gonococcus infections either alone or in combination with a sulfonamide in personnel whose services are urgently needed.

FIELD SANITATION

Purification of Temporary Water Supplies.

Recent laboratory experiments at the Naval Medical Research Institute, the National Institute of Health, and Harvard University have shown that the doses of chlorine or iodine usually recommended for the emergency treatment of drinking water are inadequate to destroy cysts of *Endamoeba histolytica* (see p. 907, *Handbook of the Hospital Corps*). It is probably necessary to add as much as 9 parts per million of chlorine or 6 parts per million of iodine to accomplish this purpose. Such concentrations also destroy cercariae of pathogenic schistosomes (*S. mansoni*, *S. japonicum*, and *S. haematobium*) (see p. 909, *Handbook of the Hospital Corps*) and the pathogenic water-borne bacteria (typhoid, paratyphoid, dysentery, and cholera bacilli). Water so treated has an objectionable taste that must be removed by dechlorination or deiodination.

To meet the foregoing requirements the Quartermaster of the Marine Corps is now procuring and issuing special water purification kits for Lyster bags and special individual superclorinating-dechlorinating units for canteens.

The kits for Lyster bags contain ampoules of grade A calcium hypochlorite (Federal Specification O–B–441a), tablets of orthotolidine for determining chlorine residual, and tablets of sodium sulfite for declorination. To treat 30–35 gallons of water, four ampoules of calcium hypochlorite are added to half a cup of water, dissolved, and then poured into the water bag. In 20 minutes a sample is tested for a chlorine residual of 3 parts per million or more, using a crushed tablet of orthotolidine in a plastic vial that has the proper indicator color printed on the surface. It is assumed that amounts up to two-thirds of the chlorine may be taken up by the organic matter in the water and that therefore a residual of 3 parts per million or more after 20 minutes is evidence of adequate initial concentration. If the residual is 3 parts per million or more, the water is dechlorinated with four tablets of sodium sulfite supplied with the kit. If the residual is less than 3 parts per million additional calcium hypochlorite is added and the water retested after 20 minutes, and then dechlorinated.

The superchlorinating-dechlorinating units for canteens now being issued consist of small (8 mm. x 21 mm. plastic, rubber-stoppered vials, each containing approximately 35 mgm. of powdered *p*-sulfonedichloramido-benzoic acid ("Halazone") and an ethyl cellulose-coated tablet containing 37 mgm. of sodium sulfite. Directions on the package instruct the user to: "Empty entire contents of one vial into canteen. Shake for 30 seconds, wait 20 minutes, then shake again for 2 minutes until the dechlor tablet dissolves."

Four to six drops of tincture of iodine (7 per cent) added to a canteen of water and allowed to act for 20–30 minutes is amoebicidal, bactericidal, and cercaricidal. The iodine taste can be removed by adding 6–8 drops of 10 per cent sodium thiosulfate.

AVIATION MEDICINE

MEDICAL PROBLEMS IN AVIATION

Introduction

Although the human body appears to be best suited to life at sea level or comparatively low altitudes, it is capable of many compensatory physiological adaptations which have enabled man to exist for longer or shorter periods at very great heights. In mountainous regions over the surface of the earth, human beings have become acclimatized to living year in and year out at altitudes several thousand feet above sea level. There are limits, however, to the capacity of the body to adapt itself to high altitudes and in modern aviation these limits are frequently exceeded. Moreover, in addition to the harmful effects of high altitudes, aviation also subjects man to the hazards of sudden changes in speed and direction of flight, as well as to extremes of temperature, noise, vibration, and motion. Added to these are the mental and physical strains associated with the dangers of combat flying. Medicine thus plays an essential role in aviation, and with the growth, development, and increasing importance of commercial and military aeronautics, there has arisen a new specialty known as Aviation Medicine. Medical officers trained and qualified in this special branch of occupational or military medicine are designated as *Flight Surgeons* or *Aviation Medical Examiners*. Officers and enlisted personnel of the Hospital Corps may also be assigned to duties in this important field.

Briefly, it may be said that the function of medical officers and Hospital Corps personnel attached to naval aviation is to keep as many efficiently functioning airmen in as many planes as possible. The carrying out of this task involves the realization of the following objectives:

(1) The development and improvement of adequate techniques for the selection of flying personnel and the determination of their medical and psychological fitness for duty.

(2) The protection and maintenance of efficiency of flying personnel by creating as favorable an environment in the plane as possible and by raising the resistance of personnel to unfavorable environment factors through training, attention to hygiene, diet, etc., and by combating fatigue by suitable and planned rest and recreation.

(3) Elimination or relocation of personnel found unfit for flight duty.

(4) Solution of medical problems in aviation through research investigations.

In this discussion some of the major problems in Aviation Medicine will be briefly considered in an attempt to indicate the scope and significance of this rapidly expanding subject.

The Rise and Growth of Aviation Medicine

Early Studies On The Rarefaction Of The Air.—The familiar mercury barometer as known today is, in principle, simply a long glass tube closed at the upper end, filled with mercury, and supported vertically with its lower end

dipping into an open container of mercury. It is known that at sea level the mercury in the tube will fall, leaving a vacuum at the top of the tube, until the mercury column is approximately 760 mm. high. Fluctuations in the height of the column occur with alterations in air pressure associated with changes in weather. It was Torricelli in 1643 who first determined the resistance to a vacuum by the use of such a vertical column of mercury. Torricelli found that the height of the mercury column below the vacuum was only one-fourteenth of the length of a corresponding water column. The news of this experiment reached Pascal who reasoned that if the mercury column was held up simply by the pressure of the air, then the height of the mercury in the tube ought to be less at high-mountain altitudes where the weight of the air was diminished. A trial of his mercury-filled tube on a high mountain in Auvergne, France, showed an actual drop of 3 inches in the level. It was thus demonstrated that the pressure of the air decreases with ascending altitude and, furthermore, a valuable instrument was discovered that could be used in the precise measurement of the barometric pressure at any altitude.

Robert Boyle, the famous seventeenth-century physicist whose name is associated with the law he enunciated relating the pressure of a gas to its volume, was the first man to study the effects of low air pressures on living animals. Boyle, with the aid of Robert Hooke, built a suction or decompression pump with which he was able to exhaust the air from a glass chamber in which he placed various small animals. He observed and described with minute accuracy the behavior of these experimental animals from their first symptoms to their final collapse. Within this simple decompression chamber Boyle thus created rarefied atmosphere, the pressure of which could be accurately measured with a mercury barometer and which reproduced, at sea level, atmospheric conditions existing at altitudes thousands of feet above the surface of the earth. In principle, the large decompression chambers in use today in Army, Navy, and civilian aeromedical laboratories for the investigation of problems in high-altitude physiology and for the indoctrination of aviation cadets are in no way different from Boyle's primitive apparatus; and in a very real sense, Boyle may be thought of as having conducted the pioneer work in high-altitude medicine.

High Mountain Expeditions and Their Relation to the Development of Aviation Medicine.—From earliest times and in widely different civilizations, mountain peaks have been associated with remarkable events and phenomena in the history of mankind. Visitors to the high-mountain altitudes have recorded strange sensations which, in the light of present knowledge, appear to have been symptoms of lack of oxygen. In 1570, for example, a Spanish priest, José de Acosta, crossed the Pariacaca mountain in Peru, at a height of approximately 14,000 feet. He returned seven years later to his native Spain and in 1588 published a description of mountain sickness as he had seen it during his travels. Numberless subsequent expeditions have been carried out into mountainous regions, some for the express purpose of studying physiological reactions to high altitudes; one of the most remarkable of these was the expedition of American and British physiologists to Pike's Peak, Colo., in 1911.

Life in high mountains involves prolonged exposure to rarefied atmosphere with acclimatization playing an important part, whereas in the case of high altitude flights in aircraft, one is concerned with relatively brief, more or less repeated exposures. The conditions imposed upon the body in mountainous climates are thus somewhat different from high altitude flying. The two have factors in common, however, and certainly aviation physiology owes much to the painstaking physiological research that has been conducted on the mountain peaks.

Thus far in this brief consideration of the development of knowledge of the high altitudes and their effects upon the body, there has been seen the emergence of the concept that the air or atmosphere surrounding the earth exerts a pressure. This pressure, which can be measured with the mercury barometer, is found to diminish as one ascends to mountain peaks. Human beings subjected to these conditions show certain adverse responses, but may become acclimatized. Above certain altitudes, however, they are no longer able to adapt themselves to the rarefied atmosphere and attempts to remain at such levels have cost many their lives. Such low atmospheric pressures can be created artificially in the laboratory within decompression chambers and their harmful effects upon man and animals observed.

Man In The Air.—Apart from mythical references to flying and Leonardo da Vinci's brilliant studies of aircraft design, little is heard of actual attempts to fly throughout ancient and medieval times and even during the Renaissance, and man remained chained to the earth until the latter part of the 18th century. In 1782, the Montgolfier brothers in Annonay, France, constructed small silk bags, filled them with warm smoke and watched them rise to the ceiling of their room. They then made larger and larger balloons of this type and finally on September 19, 1783, sent their first passengers aloft. They were, in order of their ascent, a cock, a duck, and a ram. A month later, a French nobleman, Pilatre de Rozier became the first man to fly when he ascended in a large smoke-filled balloon on October 15, 1783.

Meanwhile, experiments with hydrogen-filled balloons had been in progress and in 1785, Dr. John Jeffries, a physician from Boston, Mass., flew in such a balloon with a Frenchman, Jean Blanchard, across the English Channel from Dover, England to Calais, France.

During the years that followed, the balloon was gradually improved, and in 1862, Glaisher and Coxwell made a balloon ascent to approximately 29,000 feet. Glaisher noticed marked loss of visual acuity and hearing. His arms and legs became paralyzed and he lost consciousness. Coxwell also became paralyzed in the arms but with great presence of mind, managed to pull the valve rope with his teeth and start the balloon downward. Glaisher's account of this and other flights attracted wide attention amongst physiologists and, in particular, stimulated the interest of Paul Bert, a French physiologist who began an intensive study of drastic changes in barometric pressure.

Paul Bert's work in high-altitude physiology received additional impetus through the tragic circumstances attending the ascent of the hydrogen-filled balloon, the "Zenith", in France in 1875. This balloon left the ground with three occupants, Tissandier, a meteorologist, and two companions, Crocé-Spinelli and Sivel. Although an apparatus for supplying oxygen was taken along, this proved ineffective and at 22,900 feet Tissandier described, in notes made during the ascent, an overwhelming torpor and bodily weakness. He watched his two companions lose consciousness, but such were the effects of oxygen lack, that he had no sense of his dangerous position. On the contrary, there was a feeling of exaltation. At 26,000 feet he was so overcome that he could not even cry out. All at once, he fell down powerless and lost all further memory. The balloon ascended to 28,820 feet and then returned to earth of its own accord. Tissandier survived the experience, but Crocé-Spinelli and Sivel were dead.

The growth of Aviation Medicine in the modern sense coincides with the development of heavier-than-air craft. After the first successful flight by the Wright brothers at Kitty Hawk, N. C., on December 17, 1903, aviation advanced steadily. With the outbreak of World War I, the airplane began to be used for reconnaissance, but as the war progressed the value of the plane as

a military offensive weapon began to be recognized. It was discovered that many pilots developed neuroses during training and combat duty and it became apparent that men physically qualified for general military service were not necessarily fit to fly. Special attention to selection and protection of pilots was therefore necessary. With advances in the construction of aircraft and their range of performance at higher and higher altitudes, the insistent problem of supplying oxygen arose. It was estimated that although 10 percent of airplane accidents were attributable to mechanical failures, the great majority, 90 percent, could be traced to human errors, to some disturbance of the pilots themselves.

Recognition of the urgency of these problems lead to the establishment, early in 1918, of the Air Service Medical Research Laboratory at Hazelhurst Field, Mineola, Long Island, N. Y. From this beginning, Aviation Medicine in the United States has grown, with particular rapidity since the present war. Today, the special medical problems of flight personnel are being dealt with not only in Army and Navy and civilian laboratories, but also by Flight Surgeons attached to air stations in the United States and squadrons operating in the war theaters throughout the world. The Army School of Aviation Medicine is established at Randolph Field, Texas. The Naval School of Aviation Medicine is located at the Naval Air Station, Pensacola, Fla.

The Environment of the Aviator

The foregoing summary makes it clear that the aviator is subjected, in the execution of his duties, to conditions which differ in many respects from those on the ground. As his plane climbs into the sky, the pressure of the air around him falls markedly. It has been shown that this thinning or rarefaction of the air can be so great as to result in severe oxygen lack, leading to grave disturbances of physical and mental efficiency or even death. It will be learned that, apart from causing oxygen lack (or *anoxia*, as it is commonly called) relatively rapid reduction of barometric pressure such as occurs in high altitude flying, may also give rise to a series of painful and incapacitating symptoms known as the "bends" or the "chokes". Even if the aviator is protected from the harmful effects of anoxia or low pressures (*decompression*), there are still other problems to solve. In aviation, one is dealing with the highest speeds which man has yet attained. Actually, there seems to be no limit to the velocities which the human body can stand. For example, man is completely unconscious of the rapid rotation of the earth on its own axis. One becomes aware of traveling rapidly through space only through seeing changes in the relation of objects within the field of vision, feeling the stream of wind and the vibration of the moving vehicle, and through sensations received from the inner ears as one accelerates, decelerates, or suddenly changes the direction of the course. The forces due to *acceleration* and *deceleration* in flying or parachute jumping may be so great as seriously to disturb the body's function and, as will be seen, the aviator may suffer temporary loss of vision ("black-out"), or even lose consciousness in certain aerobatic maneuvers which subject the body to sufficient centrifugal force.

The aviator also will be subjected to complex motions about the longitudinal, transverse, and vertical axes of the airship, and in addition, must withstand the low temperatures prevailing at high altitudes or the heat of flying over desert areas. The aviator must overcome the wind and also the glare of the sun and sky, may have to fly at night and through fog, and may inhale fumes containing carbon monoxide or other toxic substances.

In the following sections, the effects of these factors in the environment of the aviator will be discussed. Although they will be considered separately here,

it must be borne in mind that many or all of them may be acting upon the flyer at the same time and that the effect of one may increase the effect of another upon the body. For example, lack of oxygen increases susceptibility to "bends", to "black-out", and to the effects of cold.

Effects of Oxygen Lack; Oxygen Administration.

ATMOSPHERIC AIR AND THE AIR IN THE LUNGS.—Air is a mixture of oxygen, carbon dioxide, nitrogen, and certain rare gases. Of these, the essential gas for the maintenance of life is oxygen. If samples of atmospheric air are analyzed it will be found that no matter from where the sample is taken, it always has the same percentage composition as follows:

	Per cent
Oxygen	20.93
Carbon dioxide	.03
Nitrogen	78.08
Rare gases (argon, helium, hydrogen, etc.)	.96

Not only is the percentage composition the same at all geographical points at the earth's surface, but also it remains unchanged at any altitude above sea level, up to approximately 70,000 feet. Failure of the air to support life at the altitudes that have been discussed is not due to a fall in the *percentage* of oxygen in the air, but rather to a *thinning* of the air, so that, say 1 cubic foot of the air at 18,000 feet, though still having the same percentage of oxygen, actually contains fewer oxygen molecules than 1 cubic foot of air at sea level. A simple analogy will serve to make this clear. Let the air surrounding the earth be represented by a pile of straw containing red straws, yellow straws, and black straws, representing, respectively, oxygen, carbon dioxide, and nitrogen. If the straws are well mixed the *percentage* of the different colored straws will be the same in all parts of the pile. However, at the *bottom* of the pile (sea level) where the straw is packed more tightly by the weight of the straws above it, there will be a *greater number* of red straws (oxygen) *per given volume* than at the top of the pile (high altitude) where the straw is looser.

Air, as has been stated, has weight or, in other words, exerts pressure. At sea level, the air exerts upon every part of the body a pressure of 14.7 pounds per square inch. That is to say, if a pipe 1 square inch cross-sectional dimensions could be shoved vertically through the atmosphere, up as far as any air exists, all this air would weigh 14.7 pounds. As Torricelli and Pascal showed, air pressure may also be expressed by the height of the mercury column in the barometer which is essentially, as previously stated, a long glass tube with a vacuum at the closed upper end and the lower open end dipping into a cup of mercury exposed to the atmosphere. At sea level, the barometric pressure, expressed in these terms, is 760 millimeters of mercury (mm. Hg), with minor variations due to weather changes. At about 18,000 feet, the air is one-half as dense as at sea level and exerts a pressure of 380 mm. Hg, just one-half sea level pressure. At about 34,000 feet, the atmosphere is only one-fourth as dense as at sea level and exerts a pressure of 190 mm. Hg or one-fourth of the pressure exerted at sea level. Expressed in another way, if a rubber balloon is filled with 1 cubic foot of air at sea level and taken to about 18,000 feet, the balloon will expand to 2 cubic feet; at about 34,000 feet, it will contain 4 cubic feet. Because a greater part of the atmosphere is close to the earth, relatively greater changes in pressure take place during the ascents and descents through distances closer to the earth than through equal distances at higher altitudes. This explains why, in ascending from sea level to 18,000 feet, the pressure drops from 760 to 380 mm. Hg, a fall of 380 mm. Hg, while a further ascent of 16,000 feet to an altitude

of 34,000 feet above the earth results in a further drop in pressure of only 190 mm. Hg. The practical application of these facts will become apparent later when the effects of ascent and descent upon the air in the middle ear and other air-filled cavities of the body are considered.

It has been stated that the total pressure of the air falls as one ascends into the atmosphere of the earth. This total pressure at any altitude may be thought of as being the sum of *partial pressures* exerted by the constituent gases of the air. The partial pressure of any gas may be obtained by multiplying the total air pressure by the percentage of that gas in the air. Thus, the partial pressure exerted by oxygen in atmospheric air at sea level is 760 × .2093 or 159 mm. Hg. The partial pressure of oxygen at 18,000 feet is 380 × .2093 or 79.5 mm. Hg; at 34,000 feet it is 190 × .2093 or 39.8 mm. Hg.

Turning now to the *alveoli*, the minute air sacs in the lungs where oxygen diffuses into the blood, it will be found that the air there also contains the same gases as atmospheric air, namely, oxygen, carbon dioxide, nitrogen, etc., but in different percentages for the reason that the *alveolar air*, as it is called, is in equilibrium with the gases in the blood. In addition, this lung air is moist, containing about 6.2 per cent water vapor. If alveolar air from human subjects be collected (a simple process), dried and analyzed, it will be found that it has the following average percentage composition:

	Per cent
Oxygen	14.2
Carbon dioxide	5.5
Nitrogen (plus the rare gases)	80.3

The partial pressure of water vapor in the alveolar air is found by calculation (760 × .062) to be approximately 47 mm. Hg and it remains constant at all altitudes studied. At sea level, therefore, the alveolar-oxygen pressure is a little over 100 mm. Hg. At this oxygen-pressure level the arterial blood leaving the lungs is about 96 percent saturated with oxygen.

At higher and higher altitudes, as the barometer pressure and partial pressure of oxygen in the atmosphere air fall, the alveolar oxygen pressure drops. As the pressure of oxygen in the alveoli falls, the percentage-oxygen saturation of the arterial blood diminishes. The lips and fingernails become blue and the skin becomes progressively more cyanotic. There is some individual difference in tolerance to high altitude but subjects taken in decompression chambers from sea-level pressure to simulated altitudes of 18,000 feet will usually lose consciousness after 45 to 75 minutes at that level. At about 51,000 feet, the alveolar-oxygen pressure drops to zero and the blood is completely unsaturated.

In flying in high altitudes, therefore, administration of added oxygen is essential. By supplying 100 per cent oxygen to the aviator his alveolar-oxygen pressure and the percentage-oxygen saturation of his blood at 34,000 feet may be maintained at approximately normal (sea level) values. Above altitudes of 37,000 feet, even with pure oxygen, he begins to become anoxic and around 40,000 feet may reach the limits of his tolerance. Above this level, even pure oxygen is so rarefied that maintenance of an adequate alveolar-oxygen pressure is no longer possible.

With this general picture of the effects of anoxia present, a brief review of some of the changes produced in various special functions of the body is desirable. Vision is impaired. Not only is the sharpness or acuity of vision diminished, but also the visual fields become narrowed. Color perception is less acute and the capacity to adapt to seeing under conditions of low illumination at night is reduced.

The functions of the nervous system are disturbed to a greater or lesser extent as evidenced by changes in reflexes and in psychological or other responses. Changes occur in the so-called "brain waves," the electrical variations which can be detected from the surface of the skull by the *electroencephalograph*. There is also good evidence that if an individual is subjected repeatedly to oxygen lack at high altitudes, permanent damage to the cells of the brain may result.

Other organs and systems of the body are also affected. The heart may do its work less efficiently and, with repeated and continued exposures to anoxia, there is a rise in the number of red blood cells (the oxygen-carrying cells) in response to a need for increased capacity of the blood to transport what oxygen is available. Adverse changes also occur in the functions of the digestive system, the liver, the kidneys, and the endocrine glands of the body.

Tolerance to Anoxia.—It is known that some individuals have a greater capacity than others to withstand conditions of inadequate oxygen. The factors which determine this variation in tolerance are, however, not completely understood. Young individuals in general appear to be more resistant than older subjects. Physical fitness tends to be associated with higher resistance.

Oxygen Administration.—Obviously, the best way to solve the problem of oxygen lack is to give extra oxygen. Space does not permit detailed consideration of oxygen equipment. It may be briefly stated, however, that oxygen should be used by all personnel under the following conditions:

(1) Oxygen should be used in aircraft in which oxygen equipment is provided: (*a*) On all flights when above 10,000 feet; (*b*) on all flights of more than 4 hours' duration between 8,000 and 10,000 feet (for a minimum of 15 minutes out of every hour); and (*c*) on night flights when above 5,000 feet (with the exception of personnel whose acuity of night vision is not essential);

(2) Personnel flying naval aircraft *not* provided with oxygen equipment shall not exceed 15,000 feet nor continue longer than 2 hours above 10,000 feet except in emergency;

(3) Flights exceeding 40,000 feet should not be undertaken with any currently installed standard oxygen equipment unless specific authorization is given and an approved installation is provided; and

(4) Personnel are urged to use oxygen equipment whenever practicable, even at low altitudes or during flights of short duration in the interests of familiarization with equipment and increased efficiency.

Methods Of Studying The Effects Of High Altitudes On Man.—The effects of high altitudes can, of course, be studied by taking subjects on high-altitude flights. This has many obvious limitations and therefore methods have been devised to simulate or reproduce high-altitude conditions in the laboratory. A technique used particularly in World War I consisted of having the subjects breathe air mixtures containing less than 20.93 per cent oxygen. For example, air containing 10 per cent oxygen at sea level corresponds to conditions at an altitude of about 19,000 feet and 6.4 per cent oxygen to about 30,000 feet. The environment in the plane ascending to altitude can be more closely simulated in the low-pressure chamber and it is in these chambers that much of the knowledge of the effects of high altitudes is being gained.

Symptoms and Signs of Anoxia.—As has been said, individuals differ in their capacity to withstand anoxia and their responses to low oxygen vary somewhat. Usually at about 6,000 to 10,000 feet, the heart begins to beat faster and respiration is stimulated. Between 10,000 and 18,000 feet, the pulse usually continues to increase and breathing is deeper. There may be some headache or a sense

of tightness across the forehead and lassitude or sleepiness. If the subject remains at 18,000 feet, the lips and fingernails become blue and cyanotic and the skin assumes an ashy hue. Attention to and accuracy of performance of duties are impaired, but such is the insidious nature of the effects of low oxygen that the aviator is usually unaware that anything is wrong. On the contrary, he is even happy and euphoric. As he continues to ascend, his intellect becomes less and less keen, and, like one under the intoxicating influence of alcohol, he uses poor judgment and yet may believe that never before has he done so well. A certain number of individuals may faint at this stage. Others go on, becoming more and more incoordinated. There is intense bodily weakness and finer movements such as writing and operation of controls become jerky and ataxic. Responses are delayed and there is gradual progressive paralysis of the legs, trunk, arms, and neck. The sensations become dulled; sharpness of vision earlier, hearing usually later. Finally, there are muscular tremors developing into violent twitching and convulsive seizures and culminating in failure of respiration; or the breathing may become irregular, then of a gasping character, and may finally cease without the onset of convulsions.

Effects of Pressure Changes.

DECOMPRESSION SICKNESS ("BENDS", "DIVER'S ITCH", "CHOKES", ETC.)—In rapid ascents in aircraft, personnel, even though supplied wiht oxygen, may experience certain symptoms which may be grouped together under the term *decompression sickness*. These manifestations generally appear at altitudes of 30,000 feet and above, and are often initiated by sensations of heat and cold and itching of the skin. There may be watering and burning of the eyes. Most characteristic are pains in muscles and joints, especially in the shoulders and knees. These may be mild and of short duration or may become progressively more severe until they are so excruciating as to lead to collapse. The condition appears to be closely related to similar pains experienced by divers in ascending from the sea-bottom which, because they sometimes cause the victim to be doubled up with backache, are known commonly as the "bends". A small percentage of subjects at high altitudes experience the "chokes", characterized by breathlessness, cough, choking and severe pain behind the sternum (breast bone), and tightness in the chest. Fortunately, all these symptoms tend to disappear rapidly when personnel are brought down to levels between 20,000 and 25,000 feet, although sometimes delayed effects are seen.

Decompression sickness appears to be related to the formation of gas bubbles in the blood vessels and the tissues of the body. As is known, the blood and other body fluids carry gases (oxygen, nitrogen, carbon dioxide, etc.) in solution. As the pressure falls in ascents to high altitude from sea level (or, in divers, from the sea-bottom to the surface), these gases tend to go out of solution. If ascent is sufficiently slow, there is time for the gases to diffuse out through the lungs, but with rapid ascents, bubbles may be formed within the body. Factors operating in the formation of these bubbles are not fully known. They have been detected in joints during severe "bends" but their precise relationship to the pain has not been clearly established. It is known that individuals differ in their susceptibility to "bends", young, fit, lean subjects tending to be more resistant. Exercise during altitude runs definitely increases the incidence of "bends" and prior administration of oxygen abolishes or reduces the frequency and severity of the condition. In aircraft with "pressure cabins", in which the pressure within the plane is maintained within limits correspondng, say, to altitudes below 15,000 feet, "bends" would not occur.

PRESSURE CHANGES IN AIR-FILLED CAVITIES IN THE BODY.—It will be recalled that air in a balloon expands with ascent and contracts again with descent. This

is of considerable importance in flying because the body contains certain air-filled spaces or cavities in which such changes in air volume may cause symptoms. During ascent, air in the middle ear expands and the excess is normally expelled through the Eustachian tube into the throat, thus equalizing the pressures. During descent, however, return of air back into the middle ear is somewhat more difficult because the Eustachian tube is ordinarily closed. The effect noticed is a temporary partial deafness. Various maneuvers, such as swallowing or holding the nose, closing the mouth, blowing and at the same time swallowing, help to open the Eustachian tube and permit the return of air to the middle ear as the plane loses altitude. Because of the relatively greater pressure changes closer to the earth, the effects on the middle ear are greater as one descends.

Personnel suffering from colds or catarrh ought not to fly unless absolutely necessary, for in such conditions the Eustachian tubes may be blocked. Flight personnel may suffer from acute inflammation of the middle ear (*aero otitis media*) brought on by faulty ventilation of the middle ears. In cases with infected, obstructed sinuses, also, flying causes expansion and contraction of the air within these cavities with resulting pain. Pain may also be caused during ascents by expansion of gases normally present in the intestine, and in certain abnormal conditions such as lung cavities or air in the pleural spaces (*pneumothorax*) ascent to high altitudes may be harmful. Special consideration must be given to patients with such conditions when transported by air.

Acceleration in Aviation.

At rest, the body is held to the earth by a gravitational force sufficient to impart to an object falling freely in a vacuum, an acceleration of 32 feet-per-second per second. This force of gravity acting upon the body at rest is expressed as 1 g. In a moving plane, changes in velocity or in the direction of movement induce forces greater than the force applied to the body at rest and which may be expressed in terms of multiples of g. The following types of acceleration may be experienced in aircraft:

(1) Radial or centrifugal acceleration. (Change in direction of movement.)
(2) Linear acceleration. (Change in velocity.)
(3) Angular acceleration. (Rotation of the body about one of its axes. In the plane this is not fast enough to cause effects except on the sense of position.)

Radial Acceleration.—An airplane changing the direction of its movement, that is to say, flying along the curve of a circle, has acting upon it a centrifugal force along an axis which coincides with the radius of the curvature of the turn. High amounts of the g produced in this way may be experienced in steep pull-outs, long, tight turns, spiral maneuvers, or any combination of fighter acrobatics. In any such maneuvers the amount of g developed increases with the square of the air speed and varies inversely with the radius of the turn and is derived from the formula:

$$g = \frac{V^2}{32.2\,r}$$

(Where V=air speed in feet per sec.;
r=radius of the turn in feet;
g=the gravitational unit.)

Thus, a plane traveling at 300 miles per hour along the circumference of a circle with a 500-yard radius is subjected to 4 g, while at 420 miles per hour with the same radius, the centrifugal force is nearly 8 g.

By convention, centrifugal forces acting upon the longitudinal axis of the body in the direction of head to feet are designated as $+\,g$, while those in the opposite direction are spoken of as $-\,g$. In the maneuvers referred to before, the principal concern is with $+\,g$ forces, although in outside turns, etc., the body

is occasionally subjected to centrifugal forces acting towards the head. Under the influence of forces greater than + 1 *g*, the body has a sensation of being increasingly heavy; at + 3 *g* the extremities feel very heavy and the pilot notices increased pressure on the feet and seat. As the + *g* force increases, the apparent weight of the body increases and also the apparent density of the blood, so that there is a greater than normal drop in arterial blood pressure between the heart and the brain. Also, blood tends to pool in the blood vessels of the abdomen and lower extremities, resulting in reduced output of blood from the heart. Therefore, with sufficiently high + *g*, acting for a sufficient time, there will be inadequate circulation of the blood in the retina and in the brain, leading first to dimming of vision, followed by "black-out", and finally unconsciousness. Individuals vary in their capacity to withstand high + *g*. The time during which the centrifugal force is applied is an important factor; for instance, a given pilot may not "black-out" when subjected to + 6 *g* for 1 second but would "black-out" in a tight turn in which + 6 *g* was sustained for 5 seconds. It is very likely that reduction of efficiency results from + *g* forces below dimming or "black out" levels. Although vision returns within a few seconds after the forces have ceased to act, there may be mental confusion for some minutes and it is possible that repeated exposure to + *g* may be a factor in chronic fatigue in aviators.

Protection against the effects of high + *g* may be afforded by tensing the abdomen, raising the lower limbs, crouching, and other procedures designed to reduce the flow of blood towards the lower part of the body from the heart.

Negative *g* forces tend to drive the blood into the upper parts of the body, causing congestion in the brain. Pilots are subjected to — *g* forces on going into a dive. A force of — 3 *g* to — 4 *g* produces an intense sense of fullness in the head, reddening of the visual field and even unconsciousness. After-effects of such — *g* may persist for some minutes or hours.

Linear Acceleration.—The most marked effects of linear acceleration are experienced by flight personnel under the following conditions:

(1) Catapult take-offs;
(2) Deceleration caused by engaging the arresting gear in carrier landings and by crashes and crash landings; and
(3) Deceleration caused by parachute opening.

In catapult landings, forces of 2 to 4.5 *g* may act upon the body in the anterior to posterior direction for 1 to 2 or more seconds, but as acceleration up to as high as 17 *g* in this axis may be tolerated, there is no real difficulty, provided the head and body are well braced. In carrier landings, deceleration forces of 2 to 4 *g* acting through 2 to 3 seconds may be experienced. In crashes, forces of 10 to 12 *g* and even 45 *g* or higher may be produced. Efficient safety belts and shoulder harness tend to prevent the head and body from being thrown forward and may save a life in such cases. Parachute openings do not usually induce sufficient force to cause "black-out." However, if a pilot pulls the rip cord immediately on leaving a very fast-moving plane he may be subjected to forces of 10 to 14 *g*, acting in the direction of head to feet. If he is receiving an inadequate supply of oxygen, the danger of "black-out" is increased.

Other Problems

Air sickness (Motion sickness).

Air sickness, like sea sickness, train sickness, swing sickness, etc., is a form of motion sickness. It is caused by overstimulation of sense organs, particularly in the inner ear, the eyes, and the abdominal viscera. Such overstimulaton re-

sults from vertical, rotatory, lateral, and surging motions caused by rough air and the aerodynamic characteristics of the plane. Bad smells, poor ventilation, inadequate oxygen supply, and uncomfortable temperatures may all increase the likelihood of air sickness, and fear, tension, anxiety, and other emotional factors play important roles.

Cold.

The temperature falls about 2° C. for every 1,000 feet of ascent until 35,000 feet is reached. At this level and above, the temperature tends to remain at about —55° C, although local variations do occur. Exposure to such intense cold markedly lowers efficiency unless adequate protection against heat-loss is afforded. Heating the cabin is of value, but is not sufficient at high altitudes. Protective clothing should not be uncomfortably tight or constricting and should be made of materials which will trap dead air within the fabric. Electrically-heated garments present certain advantages. Adequate oxygen supply is essential during exposure to cold.

Seeing at Night.

One of the most important requirements of the aviator is the ability to see dimly illuminated objects during flight operations at night. The central part of the retina (containing the *cones*) is sensitive to bright lights and to colors and is thus primarily concerned with day vision, while the *rods* (in the outer part of the retina) are concerned largely with night vision. (See section on Night Vision in this addendum.) A pilot leaving a brightly lighted ready room for a night flight will not see in the dark with maximum efficiency until he has become *dark-adapted*, that is, until the rods have reached their maximum sensitivity, and this change ordinarily requires about 30 minutes. It is now possible for flight personnel to become dark-adapted in ordinarily lighted rooms by wearing red goggles which transmit light of a color (600 millimicrons or longer wave length) to which the rods are relatively insensitive, but which permit cone vision and so allow ordinary visual tasks. Lighting of instruments in the cockpit should be designed so as not to impair dark adaptation.

"Pilot Fatigue."

Considering the strains to which flight personnel are exposed, it is not surprising that, even though they are highly selected, physically fit, emotionally stable young men, they may suffer from fatigue, especially in combat areas. So-called "pilot fatigue" is a complex condition and its causes are by no means fully understood. It has its counterpart in many other types of work requiring long hours of attention and the exercise of skill in the operation of complicated instruments. Many or all of the factors which have been discussed in this section, together with emotional disturbances arising from combat conditions, may be responsible for its onset. As in various types of industrial fatigue, "pilot fatigue" may be prevented by insuring that conditions under which pilots live and carry out their duties be as favorable as possible, and that regular and adequate periods of rest and recuperation be provided.

CHEMICAL WARFARE

Recent developments necessitate a new evaluation of the various gases that might be used by the enemy, or in retaliation by United States forces. Hospital corpsmen must be able to recognize the various gases and must know their effects upon the body, the signs and symptoms they produce, and the measures developed for *self aid*, *first aid*, and *treatment* following exposure to them. Self aid by the gassed individual must be immediate because of the rapidity with which war gases work and because delay becomes serious and possibly fatal.

The aim of the instructions that follow is to acquaint hospital corpsmen with the aforementioned aspects and the instructions are supplementary to the section titled Chemical Warfare in the *Handbook of the Hospital Corps*, pages 862 to 872.

The agents used in chemical warfare are classed according to their physiological action on man as: (1) Choking gases (lung irritants), (2) blister gases (vesicants), (3) blood and nerve poisons, (4) tear gases (lacrimators), (5) vomiting gases, (6) screening smokes, and (7) incendiaries. Each of these agents, with one exception, is designated by a symbol which symbol is shown next after the name of the agents as listed under the various classes.

1. CHOKING GASES (LUNG IRRITANTS)

The agents in this class are:

I. Phosgene (**CG**) and Diphosgene (**DP**)
II. Chlorpicrin (**PS**)
III. Chlorine (**CL**)
IV. Nitric (Nitrous) Fumes.

I. Phosgene and Diphosgene.

A. Recognition.—Casualties from phosgene and diphosgene present essentially the same symptoms and require identical measures of treatment. The odor of each suggests musty or burned hay, silage, or green corn. Their presence makes tobacco smoking disagreeable.

B. Protection.—The gas mask protects. Hold the breath instantly on detection, apply mask, and exhale as completely as possible. SPEED is absolutely essential.

C. Effects on the Body.—Phosgene and diphosgene injure the lungs and irritate the eyes, nose, and throat, but have no effect on the skin.

D. Signs and Symptons.—(*1*) immediate: There may be no symptoms but usually there are varying degrees of dryness of the throat, coughing and choking, tightness across the chest, transient slowing of the pulse, headache, nausea, and at times smarting and watering of the eyes; (*2*) later: Regardless of the severity or mildness of the initial symptoms, pulmonary edema may or may not develop 2 to 24 hours after the exposure. Developing edema is indicated by flushing of the face, shallow rapid breathing, rales throughout the chest, hacking and painful cough, frothy sputum, and cyanosis. Weak heart action, low blood pressure, clammy skin, and ashen color may follow, presenting a shock-like picture with a grave prognosis.

E. Treatment.—

(*1*) first aid: (*a*) Protect from further exposure to gas by immediate application of mask; (*b*) Moderate activity is permissible while there is no evi-

dence of pulmonary edema. However, absolute rest is mandatory when pulmonary edema is present as shown by respiratory distress; (*c*) Blankets and hot drinks may be given to keep the patient comfortably warm. Excessive application of heat is to be avoided.

(*2*) SPECIFIC THERAPY: (*a*) *Oxygen* should be given in as high a concentration as possible to relieve cyanosis. Expiration against positive pressure of from 1 to 6 cm. of water may be tried if the use of oxygen is not effective.

(*b*) *Sedation:* If oxygen fails to quiet the patient, ⅙ to ¼ grain of morphine should be used, providing respiration is not greatly depressed. Codeine is useful to relieve cough.

(*c*) *Chemotherapy:* Sulfadiazine should be given for the prevention of pulmonary infection as soon as the edema begins to subside as evidenced by the improvement in the patient's general condition. An initial dose of 2 Gm. should be followed by 1 Gm. every 6 hours for from 5 to 7 days until the threat of infection has passed. During the time sulfadiazine is being given, attention should be directed to the water intake and urinary output. The latter should not be less than 1 liter per day. A neutral or slightly alkaline urine must be maintained by the administration of 2 Gm. of sodium bicarbonate every 4 hours.

(*d*) *Venesection:* This procedure cannot be recommended. There is no proof that it is beneficial and it is distinctly harmful during the shock-like state.

F. OTHER MEASURES.—Expectorants are of no value in the acute phase of pulmonary edema. Intravenous fluids are contraindicated. Cardiac and respiratory stimulants are of little value.

G. CONVALESCENT CARE.—Absolute rest must be continued as long as pulmonary edema persists. Activity may be resumed gradually on its disappearance.

H. PROGNOSIS.—Recovery usually follows if the patient survives 48 hours after exposure.

II. Chlorpicrin.

A. RECOGNITION.—Chlorpicrin is a colorless liquid or gas with an odor of fly paper. It is a strong lacrimator.

B. PROTECTION.—The gas mask protects. On detection hold the breath instantly. Apply the mask and exhale as completely as possible. SPEED is absolutely essential.

C. EFFECTS ON THE BODY.—Chlorpicrin in ordinary concentrations irritates the eyes. Severe exposures may result in corneal ulceration. Inhaled, the gas damages the trachea, bronchi, and lungs, leading to necrosis of the mucosa and pulmonary edema. In addition, the vapor of chlorpicrin irritates the skin and the liquid can produce deep burns.

D. SIGNS AND SYMPTOMS.—Irritation of the eyes with profuse tearing occurs immediately. Pain in the chest, cough, nausea, and vomiting and the signs of pulmonary edema follow.

E. TREATMENT.—The irritation of the eyes, nose, mouth, and throat may be relieved by irrigations with water or 2 per cent sodium bicarbonate solution. Codeine allays the cough and steam inhalations reduce the tracheo-bronchial irritation. The pulmonary edema is treated as that in phosgene poisoning including the use of sulfonamides for the prevention or treatment of infection.

F. PROGNOSIS.—See Phosgene.

III. Chlorine.

A. RECOGNITION.—Chlorine is an irritating, easily visible, greenish-yellow gas with an odor like chloride of lime.

B. Protection.—The gas mask protects. Hold the breath *instantly* on detection. Apply the mask and exhale as completely as possible. SPEED is absolutely essential.

C. Effects on the Body.—Chlorine is extremely irritating to the eyes, nose, and throat on relatively heavy exposure. It devitalizes the lining membrane of the air-passages which may slough and cause obstruction. With sufficient exposure pulmonary edema follows immediately.

D. Signs and Symptoms.—Coughing, dryness of nose and throat, tightness across the chest, smarting and watering of the eyes follow immediately on exposure and continue as pulmonary edema appears. The signs and symptoms of this edema are similar to those in phosgene poisoning, but are much more frequently followed by those of broncho-pneumonia.

E. Treatment.—The treatment is the same as that outlined under Phosgene. Sulfonamides are definitely indicated as soon as the condition of the patient allows. In addition, the irritation of the eyes and nose may be relieved by irrigation with water or 2 per cent sodium bicarbonate solution followed by the instillation of anesthetic eye drops.

IV. Nitric (Nitrous) Fumes.

A. Recognition and Occurrence.—Nitrous oxides, chiefly nitrogen dioxide, result from the burning or incomplete combustion of explosives. They may occur in dangerous concentrations in poorly ventilated ship magazines, gun turrets, gun pits, and in armored vehicles. Nitrogen dioxide may be used as a war gas.

B. Protection.—The gas mask protects.

C. Effects on the Body.—Nitric fumes are insidious respiratory-tract irritants and when absorbed may produce systemic injury. Like phosgene they so damage the bronchioles and alveoli of the lungs that pulmonary edema with progressive anoxemia and hemoconcentration develop.

D. Signs and Symptoms.—Dangerous concentrations may produce little or no discomfort, or may give rise to coughing, choking, perhaps slight headache, nausea and some dizziness. One to two hours later there may be severe respiratory difficulty due to increasing pulmonary edema. Symptoms of central nervous system injury may develop after extensive exposure.

E. Treatment.—(*1*) self aid is like that for phosgene poisoning. Put on the gas mask immediately to prevent further exposure, or if conditions permit get into fresh air. If there is heavy coughing or much tightness in the chest, keep quiet and warm.

(*2*) specific therapy of casualties with symptoms of pulmonary edema is like that for phosgene. It includes absolute rest, oxygen inhalations, sedation, and chemotherapy to combat pulmonary infection.

F. Prognosis.—(*1*) Fatal cases usually die within 48 hours.

(*2*) Bronchopneumonia and varying degrees of pulmonary fibrosis and emphysema often follow the acute processes.

2. BLISTER GASES (VESICANTS)

The agents in this class are:

V. Mustard (**H**)
VI. Nitrogen Mustards (**HN**)
VII. Lewisite (**L**)
VIII. Ethyldichlorarsine (**ED**)
IX. Phenyldichlorarsine (**PH**)
X. Mixtures (Lewisite or another arsenical with Mustard or Nitrogen Mustard)

V. Mustard.

A. Recognition.—Mustard liquid looks like an oil splash on the skin, clothing, deck, bulkhead, or ground. The vapor can be seen only in concentrations where it

appears as a colorless mist. Both liquid and vapor are dangerous. The garlic-like odor may make recognition possible, but the odor may be slight and masked by other odors.

B. PROTECTION.—*The use of protective equipment is the best way to avoid injury.*

(*1*) The gas mask protects the eyes, face, and lungs from liquid and vapor.

(*2*) The eye shield protects the eyes from liquid but not from vapor.

(*3*) Protective clothing and protective ointments S–461 or S–330 shield the skin from vapor and to a lesser extent from liquid.

(*4*) After exposure without adequate protection immediate *SELF AID* is essential.

C. EFFECTS ON THE BODY.—Mustard damages the eyes, skin, and respiratory tract, and if absorbed produces systemic poisoning.

D. SIGNS AND SYMPTOMS.—(*1*) IMMEDIATE: *Contact with mustard liquid or mustard vapor causes no eye or skin pain or any other immediate symptoms. This is a most important point in differentiating mustard from arsenical gases.*

(*2*) LATER: (*a*) *Eyes.*—In 2 to 36 hours the contaminated eyes water, feel gritty, and become increasingly sore. They are "bloodshot" and lids are red and swollen. With more severe exposure the cornea and iris may be involved. Infection may be superimposed.

(*b*) *Skin.*—The vapor will burn any area of the skin, but the burn will be most severe in moist areas (neck, genitalia, groins, axillae, bends of knees and elbows). The liquid burns at the area of contact. Redness of the skin follows in 2 to 36 hours depending on the severity of exposure. Itching of the affected parts often is intense. Blisters may appear in the reddened areas at any time up to several days, or they may not appear at all. Stiffness, edema, and throbbing pain may be present.

(*c*) *Respiratory Tract.*—Inhalation of mustard gas is followed, after a number of hours, by irritation of the throat, hoarseness, and cough. Severe exposures may result in a massive slough of the mucous membranes of the trachea and bronchi, with obstruction casts. Chemical irritation of the lungs is frequent, often with possible superimposed bacterial infection.

(*d*) *Systemic Poisoning.*—Following very extensive contamination there are usually nausea and vomiting. A shock-like state may develop.

E. IMMEDIATE TREATMENT.—*Self aid is the individual responsibility of all ranks and must be accomplished immediately, after contamination.*

(*1*) If exposed to *vapor*, put on the gas-mask at once.

(*2*) If splashed by *liquid* mustard, *Self Aid* as follows:

(*a*) GENERAL: 1. Decontaminate at once. Do not expect or wait for help from others.

2. Speed is essential. Each second lost will increase final damage.

3. Mustard vapor inhaled from splashes on skin or clothing will damage the lungs and air passages. This means that every effort should be made to avoid breathing the fumes.

4. All decontamination must be completed as rapidly as possible, preferably within the first 5 minutes.

(*b*) SPECIFIC: On contamination each individual will carry out all of the following procedures precisely and as rapidly as possible in the following order:

1. Irrigation of eyes: If face or eyes have been splashed hold eye open with fingers and pour water slowly from canteen or other uncontam-

inated source into one eye and then into the other. This must be done immediately after exposure; a delay of 2 minutes may result in blindness. Irrigation should last at least 30 seconds and no longer than 2 minutes. (If uncontaminated water is not available, use urine).

2. Dab or blot gross liquid from hands and rub contaminated areas thoroughly with ointment, protective, S–461 or S–330.

3. Save face, neck, and ears by blotting off gross liquid; covering and rubbing with ointment, protective, S–461 or S–330. *Do not get ointment in eyes.*

4. Put on gas mask after face, neck and ears have been decontaminated. *Mask must be on face within 3 to 4 minutes at latest after exposure.*

5. Continue decontamination elsewhere by covering untreated, exposed skin with protective ointment.

6. If tactical conditions permit, remove contaminated clothing and dispose of it so that it cannot serve as a source of poisonous fumes. These cause serious lung, eye, and skin damage.

7. After clothing has been removed, spread ointment on areas of skin possibly contaminated unless redness has developed.

8. If clothing cannot be removed, cover contaminated areas of clothing with protective ointment.

9. Bathe with soap and water as soon as conditions permit.

NOTE:—If ointment is not available, blot thoroughly with cloth or other absorbent. Gasoline, kerosene, or alcohol may be used to wash mustard off the skin. They do not neutralize mustard, and must be used in great excess or be thoroughly and promptly washed away with soap and water. Bleach also is a decontaminant, but it must be removed directly after application to avoid serious irritation of the skin.

F. LATE TREATMENT.—(*1*) EYES: (*a*) Severe irritation of the eyes may be relieved by the occasional use of local anesthetics (butyn ophthalmic ointment, two drops of anesthetic solution, or of 0.5 per cent pontocaine hydrochloride). These anesthetics should not be used unless necessary and then not oftener than every 6 hours. Cocaine is contraindicated.

(*b*) Where vision is obscured by spasm or edema of the lids, the lids should be gently opened to reassure the patient that he is not blind.

(*c*) Bandages or covering should not be put on the eye at any time. Dark glasses are to be avoided if possible.

(*d*) Sealing of the lids should be prevented by application of sterile petrolatum or sulfonamide ointment to their margins.

(*e*) The eye may be gently irrigated with boric acid solution, 2 per cent, sodium bicarbonate solution, 2 per cent, or saline solution, 1.0 to 1.5 per cent to remove foreign material, discharge, or mucus. Irrigations should be used as sparingly as possible—never routinely. Gravity-flush bottles with tubing and nozzles are advised for irrigation.

(*f*) Loss of corneal epithelium may be demonstrated by yellow-green staining of the cornea after instillation of 2 per cent solution of sodium fluorescein made slightly alkaline with sodium carbonate, followed after 30 seconds by irrigation with saline solution, 1.0 to 1.5 per cent, or sodium bicarbonate solution, 2 per cent.

(*g*) Cases with corneal ulceration may become infected unless sulfonamides are being administered by mouth. Local application of sulfonamide

ophthalmic ointment every four to eight hours is indicated beginning 24 to 72 hours after injury.

(*h*) Atropine sulfate, 1 per cent solution, or atropine ophthalmic ointment, 1 per cent, should be instilled once per day if corneal injury is present. Atropine must be discontinued at the slightest sign of developing sensitivity.

(*i*) When possible patients with corneal injury should be placed in the care of an ophthalmologist.

(*2*) SKIN: (*a*) Calamine lotion may be applied freely for itching and irritation.

(*b*) Pain accompanying blisters may be relieved by compresses wet with saline, boric acid, or amyl salicylate solution. *Caution:* Amyl salicylate, if used, should be kept away from the eyes and from the skin of the genital region.

(*c*) Any large, tense, or painful vesicle should be drained through a small incision at the edge after cleansing the skin surface with alcohol.

(*d*) Small denuded areas may be coated with sulfonamide ointment; no more than 100 Gm. of ointment are to be used and no more than 5 per cent of the body surface is to be covered.

(*e*) To avoid excessive absorption, if the burns are extensive, sulfadiazine should be given by mouth. A daily urinary output of 1,500 cc. should be maintained during sulfonamide administration (see Phosgene).

(*f*) Further treatment of mustard burn lesions, including skin grafting, is like that for thermal burns.

(*3*) RESPIRATORY TRACT: (*a*) Sulfonamides should be administered when pulmonary involvement becomes manifest (see Phosgene).

(*b*) Oxygen is indicated for relief of respiratory distress.

(*4*) SYSTEMIC POISONING requires symptomatic treatment—transfusions of plasma for shock and whole blood for anemia.

G. PROGNOSIS.—(*1*) Mustard lesions of the eye require 3 weeks to 2 months or longer for healing. Total blindness is rare. Severe corneal injury tends to be followed for many years by ulcerative recurrence.

(*2*) Skin healing is slow, but complete. Dark-brown superficially scarred areas usually remain if burns are severe.

(*3*) Deaths from respiratory tract and systemic injury may occur one day to two weeks after severe exposure.

VI. Nitrogen Mustards.

A. RECOGNITION.—Nitrogen mustards are volatile, oily, colorless or pale yellow liquids with a faint fishy odor. They are dangerous both as liquid and as vapor.

B. PROTECTION.—Protection is the same as for mustard.

C. EFFECTS ON THE BODY.—Like mustard the nitrogen mustards damage the eyes, the skin, the respiratory tract when inhaled, and produce systemic damage when absorbed. They are less vesicant than mustard but their systemic effects may be more pronounced.

D. SIGNS AND SYMPTOMS.—The signs and symptoms are the same as described for mustard except that they appear more rapidly. Some of the nitrogen mustards cause prompt and powerful miosis (contraction of the pupils of the eyes) with severe ciliary pain beginning a few hours after exposure.

E. IMMEDIATE TREATMENT.—Sequence of procedures as for mustard.

(*1*) EYES: Immediate irrigation with water, as for mustard.

(*2*) SKIN: Wash off immediately with large amounts of soap and water, or water alone. If soap and water are not available, decontaminate the skin with ointment, protective, S–461 or S–330 as directed under mustard. Ointment, protective, S–461 or S–330 does not effectively neutralize the nitrogen mustards

and, therefore, must be removed and fresh ointment reapplied and removed several times. The contaminated parts, preferably the whole body, must be washed with soap and water as soon as conditions permit. Decontamination may be carried out as late as 2 to 3 hours after contact with liquid nitrogen mustards in an effort to prevent their complete absorption.

F. LATE TREATMENT.—Late treatment of skin and respiratory tract lesions and of systemic effects is the same as for mustard. In regard to the eye, the ciliary pain can be controlled with atropine, 1 per cent. The iritis and cyclitis are also indications for vigorous local use of atropine.

G. PROGNOSIS.—The prognosis is the same as for mustard lesions.

VII. Lewisite. (L)
VIII. Ethyldichlorarsine. (ED) } **Arsenicals.**
IX. Phenyldichlorarsine. (PD)

A. RECOGNITION.—(*1*) Lewisite smells like geraniums. It is an oily, clear or light amber liquid which vaporizes slowly to a colorless gas.

(*2*) Ethyldichlorarsine is a colorless or brown liquid which vaporizes more quickly than Lewisite. It has a faint fruity odor.

(*3*) Phenyldichlorarsine is a clear viscid liquid, less volatile than either Lewisite or ethyldichlorarsine, and has an odor like shoe polish.

B. PROTECTION.—(*1*) The gas mask protects the eyes, face, and lungs from liquid and vapor.

(*2*) The eye shields protects the eyes from liquid but not from vapor.

(*3*) Protective clothing protects the skin from vapor and to a lesser degree from liquid.

(*4*) Following exposure, when protectives have not been used, prompt *SELF AID* is essential.

C. EFFECTS ON THE BODY.—The arsenicals damage the eyes and lungs, burn and blister the skin and on absorption may produce systemic poisoning. The agents are also strongly nauseating.

D. SIGNS AND SYMPTOMS.—(*1*) IMMEDIATE: A liquid arsenical in the eye immediately causes excruciating eye pain and strong spasm of the lids. The cornea becomes opaque at the point of contact. High concentrations of vapor sting and burn the eyes and when inhaled produce sneezing, coughing, pain, and tightness in the chest. Nausea and vomiting are often prominent. The liquid and very high concentrations of the vapor are almost immediately painful on the skin. Redness and blistering follow rapidly.

(*2*) LATER: (*a*) Extensive corneal damage may be followed by perforation and destruction of the eye.

(*b*) Lung damage from inhaled vapor has not been observed in man because the marked irritation of the respiratory tract forces the early application of the mask.

(*c*) Systemic poisoning from absorbed arsenic may be manifested by anemia, jaundice, and often pulmonary edema.

E. IMMEDIATE TREATMENT.—SELF AID is the responsibility of individuals of all ranks and must be accomplished immediately after contamination.

(*1*) EYES: Immediately after contamination of the eyes or face with liquid, hold breath as much as possible; pull open the eyelids with fingers, squeeze Ointment BAL directly into the contaminated eye and gently massage the lids. If the eye cannot be opened because of pain and spasm, apply Ointment BAL to the lids and rub as much as possible into the slit between them. As soon as the pain lessens and the lids can be pulled apart, squeeze additional ointment into

the eyes. *Caution*: Although Ointment BAL reduces pain in the Lewisite-contaminated eye, it causes a sharp stinging pain and blepharospasm (spasmodic blinking of the eyelid) in the normal eye. These effects are not serious. The eyes open in a few minutes and irritation disappears in about ½ to 2 hours. If pain is experienced from the BAL itself, the patient should be reassured.

(*2*) FACE AND RESPIRATORY TRACT: Decontaminate face as described in the following paragraph and put on the mask.

(*3*) SKIN: Quickly blot gross liquid from the skin with the absorbent paper furnished with the tube of Ointment BAL or with a cloth. Spread the ointment over the contaminated area and rub it with the fingers for 20 to 30 seconds. Whenever tactical conditions permit, cut, tear away or otherwise remove the contaminated clothing and decontaminate the skin beneath. Dispose of clothing so that liquid or poisonous fumes will be avoided. Bathe with soap and water as soon as possible.

F. LATE TREATMENT.—(*1*) EYES: Treatment is like that for mustard.

(*2*) SKIN: *Erythema*, blisters and ulcers are treated like those from mustard.

(*3*) RESPIRATORY TRACT: Treatment is like that for mustard.

(*4*) SYSTEMIC POISONING: To combat the systemic effects produced by absorbed Lewisite apply the entire contents of one tube of Ointment BAL to the contaminated skin. If the skin is denuded apply BAL to uninvolved areas. Spread widely and rub in well to obtain maximum absorption of the BAL. Leave the preparation on the skin and apply fresh BAL at 12 hour intervals for 48 hours and daily thereafter for 4 days. Combat shock by intravenous plasma and support patient with a high carbohydrate, high protein diet supplemented if necessary by intravenous dextrose and fluids.

X. Mixtures (Lewisite or another arsenical with mustard or nitrogen mustard).

A. RECOGNITION.—The odor of the arsenical usually masks the odor of mustard, making correct identification of the mixture difficult. Symptoms also may be confusing.

B. PROTECTION.—Protection is the same as for mustard gas.

C. EFFECTS ON THE BODY.—The effect of mixed blister gases is a combination of the specific effects of each gas in the mixture. Mixtures damage the eyes and lungs, burn and blister the skin, and on absorption may produce systemic poisoning.

D. SIGNS AND SYMPTOMS.—(*1*) There is immediate severe eye pain and almost immediate skin irritation on contact if Lewisite, ethyldichlorarsine, or phenyldichlorarsine is present in the mixture.

(*2*) The lesions produced by mixtures of an arsenical with mustard resemble those of pure Lewisite, unless the arsenical component has been promptly neutralized by specific therapy Ointment BAL. In this case they are like mustard lesions.

E. IMMEDIATE TREATMENT.—*Self aid is the individual responsibility of all ranks and must be accomplished immediately after contamination.*

(*1*) EYES: (*a*) If there is no immediate pain on contamination, it is to be assumed that mustard only is present and irrigation of the eyes as described for liquid mustard should be carried out immediately after blotting the lids.

(*b*) If there is immediate severe eye pain it is to be assumed that an arsenical is present and Ointment BAL should be used at once, as directed for liquid Lewisite. Visible droplets on the lids should be dabbed off if possible before Ointment BAL is applied.

(*2*) FACE AND RESPIRATORY TRACT: (*a*) Decontaminate face as described under "skin."

(*b*) Put on gas mask.

(*3*) SKIN: (*a*) Quickly blot all gross liquid from the skin.

(*b*) Immediately apply ointment, protective, S–461 or S–330 to the contaminated areas as described for liquid mustard. *This ointment should be kept out of the eyes.*

(*c*) Remove as much ointment, protective, S–461 or S–330 as can be done quickly and apply Ointment BAL to the same areas.

(*d*) Remove this BAL and reapply a fresh quantity which should be left on the skin.

(*e*) Remove contaminated clothing and treat underlying skin possibly contaminated as described in (*a*), (*b*), (*c*), and (*d*).

(*4*) Contaminated clothing should be cared for as described under mustard.

F. LATE TREATMENT.—Lesions due to mixtures are treated like mustard lesions. If exposure was extensive the possibility of systemic poisoning from the arsenical should be combatted by the use of Ointment BAL as directed for Lewisite.

G. PROGNOSIS.—The prognosis is the same as for mustard and Lewisite.

3. BLOOD AND NERVE POISONS (SYSTEMIC POISONS)

The agents in this class are:

XI. Hydrocanic Acid (AC) XII. Cyanogen Chloride (CC)

XI. Hydrocyanic Acid.

A. RECOGNITION.—Hydrocyanic acid is a clear colorless liquid. It volatilizes very rapidly and the odor of the resulting gas resembles that of peach kernels or bitter almonds.

B. PROTECTION.—(*1*) The gas mask protects for a limited period. Hold the breath instantly on detection, apply mask and exhale as completely as possible. SPEED is absolutely essential.

(*2*) Spraying with water will remove cyanide from the air of confined spaces.

C. EFFECTS ON THE BODY.—The effects of hydrocyanic acid usually result from inhaling the gas, less frequently from absorption through the skin or gastro-intestinal tract. Paralysis of the respiratory center terminates in death unless treatment is immediate.

D. SIGNS AND SYMPTOMS.—(*1*) Exposure to low concentrations causes giddiness, headache, and slow lapse of consciousness.

(*2*) Unconsciousness, convulsions, and death rapidly follow exposure to high concentrations.

E. TREATMENT.—(*1*) To be effective, treatment must be IMMEDIATE AND DETERMINED. Life depends upon instant action, i. e., a matter of seconds.

(*2*) Fresh air is lifesaving. If not immediately available, put on mask.

(*3*) Coma or convulsions requires AMYL NITRITE. Crush a pearl in its cloth container and place over nose or insert under mask. If necessary this may be repeated. *Warning:* A fully conscious person cannot tolerate amyl nitrite under a mask.

(*4*) Artificial respiration, in addition to (*2*) and (*3*), must be applied if breathing has stopped.

(*5*) If it is not immediately reestablished, give intravenously alternate doses of the following antidotes where available:

(*a*) Sodium nitrite (0.3 to 0.5 Gm.) in 10 to 15 cc. of water over a period of 3 minutes.

(*b*) Sodium thiosulfate (25 Gm.) in 50 cc. of water over a period of 10 minutes.

Epinephrine should be employed, if necessary to combat excessive fall in blood pressure produced by either the amyl or sodium nitrite given.

(*6*) If liquid AC has been swallowed, immediately wash out the stomach with a pint of 1 in 1,000 aqueous solution of potassium permanganate, and give intravenous sodium nitrite followed by sodium thiosulfate as outlined before under (*5*).

XII. Cyanogen Chloride (CC).

A. RECOGNITION.—Cyanogen chloride is a clear colorless liquid even more volatile than hydrocyanic acid. It irritates the nose and throat and produces lacrimation even in relatively low concentrations.

B. PROTECTION.—The gas mask protects, for a limited period. On detection, instantly hold the breath. Apply mask and exhale as completely as possible, S P E E D is absolutely essential.

C. EFFECTS ON THE BODY.—The effects of cyanogen chloride combine those of cyanogen and chlorine. Cyanogen chloride, like hydrocyanic acid gas, is absorbed through the lungs and causes rapid failure of respiration as in the case of hydrocyanic acid. The contained chlorine immediately irritates the eyes and damages the respiratory tract.

D. SIGNS AND SYMPTOMS.—(*1*). The acute signs and symptoms resulting from the cyanide component in the gas are giddiness, headache, and, in severe exposure, unconsciousness and death.

(*2*) Coughing, dryness of the nose and throat, tightness across the chest, and smarting and watering of the eyes result from the chlorine component in the gas. As with chlorine gas pulmonary edema follows severe exposures.

E. TREATMENT.—(*1*) Treatment must be IMMEDIATE AND DETERMINED.

(*2*) Fresh air or instant application of the mask is lifesaving.

(*3*) If breathing continues, recovery will probably occur without any specific therapy.

(*4*) Combat the cyanide effect by: (*a*) Inhalation of amyl nitrite fumes for convulsions and/or coma, as directed for AC gas;

(*b*) Artificial respiration if breathing has stopped;

(*c*) If these measures fail, give alternate doses of sodium nitrite and thiosulfate intravenously as directed for AC.

(*5*) Combat the chlorine effect by: (*a*) Irrigation of the eyes, nose, and throat to relieve irritation;

(*b*) Codeine to relieve cough;

(*c*) Oxygen in as high a concentration as possible to relieve the cyanosis of pulmonary edema as directed for phosgene poisoning; and

(*d*) Sulfonamides to prevent pulmonary infection, as directed for phosgene poisoning.

4. TEAR GASES (LACRIMATORS)

The agents in this class are:

XIII. Chloracetophenone (CN) XIV. { Chloracetophenone Solution (CNS) / Chloracetophenone Training Solution (CNB) }

XV. Bromobenzylcyanide (BBC)

A. Recognition.—These gases are recognized by their odors and their characteristic effect on the eyes.

CN smells like apple blossoms.
CNS smells like fly paper.
CNB smells like sweetish benzene.
BBC smells like sour fruit.

B. Protection.—Adjust gas mask immediately on recognition.

C. Effects on the Body.—Tear gases irritate the eyes, nose, and moist skin areas. Occasionally nausea and vomiting are produced. These effects are transient. The liquids, in contact with the eyes or skin, are caustic.

D. Signs and Symptoms.—Stinging, burning, and profuse watering of the eyes are produced immediately on exposure, followed later by burning of exposed moist areas especially at the edges of clothing (neck, wrists, and ankles). Splashes of liquid are immediately painful.

E. Treatment.—(*1*) Do not rub eyes. Following adjustment of the mask, the eye, nose, and throat symptoms disappear rapidly. Irritation of skin may be relieved by washing.

(*2*) Late treatment for conjunctivitis and irritation of the skin is symptomatic. Skin burns require no specific treatment.

F. Prognosis.—Symptoms following the most severe exposures to vapor seldom last more than two hours. Following moderate exposures they last only a few minutes. Cases seldom reach the attention of the medical service. Severe burns of the eyes and skin heal slowly, but recovery is complete.

5. VOMITING GASES

The agents in this class are:

XVI. Diphenylaminechlorarsine (Adamsite) (DM) 17. Diphenylchlorarsine (DA)
XVIII. Diphenylcyanarsine (DC)

A. Recognition.—These substances are solids and when heated or detonated form smokes. DM smoke in heavy concentration is yellow, whereas DA and DC are white. All become invisible on dilution with air. Heavy concentrations of DM smell like coal smoke. DA smells like shoe polish and DC like garlic and bitter almonds.

B. Protection.—The gas mask protects. Hold the breath instantly on detection. Apply mask and breathe out. The mask should be kept on in spite of salivation and nausea as these effects are only transitory.

C. Effects on the Body.—These agents in ordinary concentrations produce no permanent damage.

D. Signs and Symptoms.—"Pepper-like" burning of the eyes, nose, throat, trachea, and bronchi accompanied by lacrimation. Repeated sneezing and coughing appear soon after exposure. These symptoms increase in severity for several minutes and after a heavy exposure are followed by a sense of fullness in the head with pain in the nose, a violent frontal headache, and aching of the teeth

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and gums. There is copious nasal discharge, salivation, and often nausea and vomiting. Temporary mental depression has been described. These signs and symptoms are transitory and subside soon after removal from the gas.

E. TREATMENT.—(*1*) SELF AID demands immediate application of the gas mask and in spite of increasing symptoms it must be kept on except for lifting it during actual vomiting.

(*2*) Medical attention is seldom necessary. Whiffs of chloroform give prompt relief of nose and throat irritation. Irrigations also may be useful. Aspirin may be given to allay headache and general discomfort.

F. PROGNOSIS.—All symptoms disappear in about 1 to 2 hours. Permanent injury does not occur.

6. SCREENING SMOKES

The agents in this class are:

XIX. HC Mixture Smoke
XX. FS Smoke (Sulfur Trioxide-Chlorosulfonic Acid)
XXI. FM Smoke (Titanium Tetrachloride)
XXII. WP Smoke (White Phosphorus)

A. RECOGNITION.—These agents are visible as clouds of white smoke. They have a sharp stinging odor.

B. PROTECTION.—The gas mask is required only in concentrations higher than those ordinarily used for screening purposes. Such concentrations usually occur near the point of smoke production, or in confined spaces. *Beware of enemy smoke!* It may contain lethal agents.

C. EFFECTS ON THE BODY.—Ordinary screening concentrations produce no injurious effects. Heavy concentrations irritate the eyes, nose, throat, and lungs. Splashes of liquid FS and FM produce acid-like burns of the skin and eyes. Inhaled in relatively large quantities these smokes may produce enough pulmonary irritation to result in pulmonary edema.

D. SIGNS AND SYMPTOMS.—Following exposure to heavy concentrations, the eyes become painful and watery, there is running of the nose, coughing, and possibly a feeling of constriction in the chest. Contamination of the eyes or skin with liquid FS or FM produces immediate severe pain. These agents, particularly HC produce a feeling of suffocation which may be followed later by signs and symptoms of pulmonary edema.

E. SELF AID.—Self aid after irritating exposures includes putting on the gas mask for relief of eye, nose, and throat symptoms. The eyes and skin should be washed immediately following contamination by splash.

F. TREATMENT.—Medical treatment is seldom necessary except for severe eye and skin burns due to liquid. Following thorough irrigation of the eyes and washing of the skin, the burns are treated as any other burns. Pulmonary edema is treated as in phosgene poisoning.

G. PROGNOSIS.—Good, unless heavy concentrations have been inhaled, when pulmonary edema may develop. The prognosis of eye and skin burns is like that of acid burns of equal severity.

7. INCENDIARIES

The agents in this class are:

XXIII. White Phosphorus (WP) (Is also a screening smoke)
XXIV. Thermite (TH)
XXV. Magnesium and its Alloys
XXVI. Oil Incendiaries

A. General.—Incendiary agents burn fiercely, generating tremendous heat. White phosphorus, in burning, produces a dense white smoke, which is used extensively as a screening agent. WP smoke smells like burning matches. Oil incendiaries are used in bombs.

B. Protection.—(*1*) Burning particles are to be avoided.

(*2*) The gas mask must be worn in concentrations of white phosphorus smoke higher than those ordinarily used for screening purposes—such as might occur near the point of production or in confined spaces.

C. Effects on the Body.—Incendiaries produce severe heat burns. Particles of metal imbedded in the skin may delay healing.

D. Signs and Symptoms.—Pain is severe on contact. White phosphorus continues to burn in the skin until deprived of air.

E. Treatment.—(*1*) white phosphorus.—(*a*) Immediately immerse the burning parts in *water* and keep them there. This extinguishes the phosphorus. If the burning body or limb cannot be immersed, apply cloths or towels sopped in water or other non-irritating aqueous solution. Sodium bicarbonate, 2 per cent solution, if available, may be used.

(*b*) As soon as possible immerse the burns in 5 per cent copper sulfate solution or cover them with cloths soaked with the solution. There must be no interruption in the wetting or the phosphorus still imbedded in the skin will again ignite. Copper sulfate quickly renders the imbedded phosphorus noninflammable, by coating it with copper phosphide.

(*c*) If no copper sulfate is available, all particles of phosphorus imbedded in the skin must be removed under water. If the copper sulfate has been applied, the particles can be removed in air without danger. Particles may be detected by their phosphorescence. Burning particles are recognized by the evolution of smoke.

(*d*) Following removal of the particles, phosphorus burns are treated as thermal burns. Ointments and oily dressings, however, should not be used, as these may dissolve phosphorus and allow it to be absorbed. The risk of systemic poisoning is small, unless oily dressing are used.

(*2*) thermite (th), magnesium, oil incendiaries.—Bits of metal imbedded in the tissues should be promptly searched for and removed. The further treatment of burns from these agents is like that of thermal burns.

CHEMICAL WARFARE REFERENCE CHART

Tactical class	Physiological class	Symbol	Name	Odor	Color and state	Persistence	Effect on body	Protection	SELF AID Must be immediate
CASUALTY GASES	BLISTER GASES	H	MUSTARD	Garlic; horse radish.	Dark oily liquid; colorless gas.	1 day to all winter.	No immediate symptoms. 3 to 36 hours later irritates eyes, skin, nose, lungs. Worse in tropics.	Gas masks. Eye shields. Protective ointment. Protective clothing. Protective covers.	*Eyes.* Wash out with water. *Skin.* Blot off liquid. Rub in ointment S–461 or S–330. Do not use in eyes or on reddened skin. *Clothes.* See L.
		HN	NITROGEN MUSTARDS	Faint fishy	do	2 hours to days			
		L	LEWISITE	Geraniums	do	1 day to 1 week	Immediate stinging pain of eyes and skin. Irritates nose, throat, and lungs.		*Eyes.* Squeeze ointment BAL into eyes. *Skin.* Blot off liquid. Rub in ointment BAL. Do not use on reddened skin. *Clothes.* Remove contaminated clothing and discard. Avoid fumes. Treat underlying skin.
		ED	ETHYLDICHLORARSINE	Biting; stinging.	Colorless or brown liquid; colorless gas.	1 to 12 hours			
		PD	PHENYLDICHLORARSINE.	Shoe polish	Clear viscid liquid	Hours to days			
		MIXED	H & L, HN & L, etc	Combination of H & L.	Combination of H & L.	Varies	Combination of H & L.		*Eyes.* Ointment BAL. *Skin.* Ointment S–461 or S–330. Remove. Use BAL. *Clothing.* As L.
	CHOKING GASES	CG	PHOSGENE	Musty hay; green corn.	Colorless gas	1 to 10 minutes	Coughing. Choking. Difficulty in breathing. Fluid in lungs.	Gas mask	Rest and comfortably warm.
		DP	DIPHOSGENE	do	do	30 minutes			
		PS	CHLORPICRIN	Flypaper; licorice.	Yellow oily liquid; colorless gas.	1 hour to 1 week.	Irritates eyes. Same as CG.	do	Rest and comfortably warm. Wash eyes, nose, and throat for irritation.
		CL	CHLORINE	Chloride of lime.	Greenish-yellow gas.	10 minutes to 1 hour.	Same as PS	do	Same as PS.
	BLOOD AND NERVE POISONS	AC	HYDROCYANIC ACID	Bitter almonds	Colorless liquid or gas.	1 to 10 minutes	Dizziness. Headache. Coma.	do	Whiffs of amyl nitrite. First aid if not breathing is artificial respiration.
		CC	CYANOGEN CHLORIDE	Biting	do	do	Irritates eyes, nose, throat. Also as AC.	do	
HARASSING GASES	TEAR GASES	CN	CHLORACETOPHENONE	Apple blossoms.	Cloud of particles or droplets.	10 minutes to weeks.	Irritates eyes. Heavy concentration irritates nose, throat, and lungs. Burns and blisters skin in warm climates.	do	Wash out eyes with water and wash skin with soap and water. Face upwind. Additional self-aid usually not necessary.
		CNS	CHLORACETOPHENONE SOL.	Fly paper	do	1 hour to 1 week.			
		CNB	CHLORACETOPHENONE TRAINING SOL.	Sweetish benzine.	do	Not determined.			
		BBC	BROMBENZYLCYANIDE.	Sour fruit	Colorless liquid or gas.	Days to weeks			
	VOMITING GASES	IM	ADAMSITE	Coal smoke	Yellow cloud	10 minutes	Vomiting. Irritates eyes, nose, throat. Headache.	do	Sniff chloroform. Keep masked. Lift mask only when actually vomiting. Additional self-aid usually not necessary.
		DA	DIPHENYLCHLORARSINE.	Shoe polish	White or gray cloud.	5 to 10 minutes			
		DC	DIPHENYLCYANARSINE	Garlic; bitter almonds.	White cloud	do			
SCREENING SMOKES		HC	HEXACHLORETHANE MIXTURE.	Sharp; stinging.	White to gray smoke.	While burning	Heavy concentration irritates eyes, nose, throat. FS and FM liquid burns skin.	Gas mask for heavy concentrations.	Wash out eyes if irritating. Wash skin burns with water. Additional self aid usually not necessary.
		FS	SULFUR TRIOXIDE	do	Dense white smoke	5 to 10 minutes			
		FM	TITANIUM TETRACHLORIDE.	do	White smoke	10 minutes			
		WP	WHITE PHOSPHORUS	None or burning matches.	Burns to white smoke in air.	do	Burns skin	Avoid burning particles.	Keep wet with water, or cover with copper sulfate. Remove particles. Do not use grease or salve.
INCENDIARIES		TH	THERMITE MAGNESIUM BOMB.	None	White hot metal; burns with white light.		Heat. Burns	do	Cool burning material and remove. Treat as any burn.
		IMNP	THICKENED GASOLINE.	Burning oil	Yellow jelly; black smoky flame.			do	

DIVING AND SUBMARINE DUTY

The information concerning various aspects of submarine medicine that follows is for the guidance of hospital corpsmen on submarine duty and is supplementary to the section titled "Diving and Submarine Duty" in the *Handbook of the Hospital Corps*, pages 827 to 879.

Hospital corpsmen who serve on submarines are usually chief pharmacist's mates and pharmacists' mates, first class, or pharmacist's mates, second class, who should soon be rated first class. Before being assigned to duty on submarines pharmacist's mates must undergo a period of training at the Submarine Base, New London, Conn., to fit them for that type of duty. They first receive a six-weeks' course of instruction in all duties they will be required to perform aboard a submarine at the School for Pharmacist's Mates Entering the Submarine Service. Upon graduation from that school they receive further training in submarine work at the Submarine Basic School.

Submarines are navigable vessels so constructed that they can operate either on or below the surface of water. The pressure hull is divided into several compartments or sections by watertight, thwart-ship bulkheads. Submarines have main ballast tanks which are empty (or "dry") during surface operations and are flooded upon and during submergence. To bring a submerged submarine to the surface the water is blown from the main ballast tanks with compressed air. Minor variations in the over-all weight of a submarine resulting from the addition or use of stores, fuel, etc., are compensated for by flooding or emptying the variable tanks.

Because of the unusual construction and function of submarines there are numerous problems of a medical nature which need emphasis, particularly air conditioning, diet, maintenance of health and sanitation, and selection of personnel.

SUBMARINE VENTILATION

The ventilation system on a submarine has three primary functions. It must maintain acceptable conditions of habitability so that the crew can function properly at all times. It must provide sufficient air for the engines when they are operating. It must meet the requirements for battery ventilation under the various conditions of battery operation. By reason of the nature of the structure of a submarine certain items concerned with ventilation merit special consideration. Some of these items are:

(*a*) The necessity for watertight compartmentation;
(*b*) Carbon dioxide accumulation and oxygen depletion while submerged;
(*c*) The possibility of the accumulation of hydrogen to a dangerous concentration either when on the surface or when submerged; and
(*d*) The possibility of the presence of toxic gases from the engines or batteries, or from other sources, either during normal operations or as the result of damage to the vessel.

The ventilation system of a submarine is designed to provide efficient and adequate ventilation when on the surface regardless of whether the engines are run-

ning or stopped, whether any hatches are opened or closed, whether the vessel is cruising or lying to, whether the bulkhead doors are open or closed, and when submerged with ventilation inboard and bulkhead doors either open or closed.

A submarine ventilation system thus becomes a compromise between the various factors involved and cannot be expected to operate to the best advantage at all times. The entire personnel of the service whose duties require their consideration of the questions of design, maintenance, and operation of the ventilation of submarines should give all these factors most careful study so that the principle and practice of submarine ventilation will be constantly improved.

Air pressure.

The air in a submarine is normally under the same pressure as that of the outside air. During a dive the pressure increases slightly owing to compression of the hull and to venting of the tanks inboard. However, should an escape with the submarine-escape appliance (the lung) be necessary, the air pressure within the compartment which is being flooded must be permitted to increase until it equals the pressure of the sea water for a depth at which the submarine is submerged (which allows the opening of the escape hatch).

Air Movement.

When the vessel is submerged the air movement is controlled by the same may be accomplished naturally through the hatches, which is called natural ventilation. However, it is often necessary to close all the hatches except the conning tower hatch and in that case air is taken through this hatch and the main induction system; this is called artificial ventilation. All watertight doors between an open hatch and running engines should be kept open to prevent a sudden decrease in air pressure in the engine room and all compartments aft of it, if the main induction is accidentally closed. The decrease in air pressure would be so sudden and so complete in this case that it would result in the death of every man in these compartments. Forced-draft blowers take air through the main induction and distribute it into the various compartments of the ship. An exhaust system is provided which takes air from the various compartments and delivers it to the engine room where it is discharged through the engines. All ventilation on the surface is called outboard.

When the vessel is submerged the air movement is controlled by the same system, except that air is no longer exhausted through the engines but is returned to the supply system through the air-conditioning unit, which cools and dehumidifies it. These methods of air movement are supplemented by use of compartment electric fans and portable blowers and are called inboard ventilation.

On the typical submarine, engine air is supplied through the main engine air-induction valve located in the conning tower fairwater and through outboard piping to the engine room via hull valves. The engines take their air from the engine room. The ship's ventilation supply air enters through the hull ventilation induction valve, also located in the conning tower fairwater, through outboard piping and a hull valve to the hull supply fan.

Ventilation distribution within the vessel is achieved by means of a supply duct and an exhaust main duct within the vessel, each running the entire length of the ship and each provided with branches in each compartment. The hull ventilation fans are located in one of the compartments near the longitudinal center of the vessel. The exhaust is so arranged that it can be discharged to the engine room or engine air-induction pipe when the engines are running, and

can be discharged overboard via the engine air-induction piping when the engines are stopped. All vessels are provided with some kind of a cross connection between the exhaust-fan discharge and the supply-fan intake, so that the fans may be used for recirculation of the ship's air while submerged.

Proper ventilation on submarines is of primary importance. In a sealed compartment such as a submarine the air is vitiated by the consumption of oxygen and the production of carbon dioxide and moisture by the ship's company, by the production of heat from machinery, gases from cooking, the batteries, lubricants, etc.; and during the charging of the batteries, by hydrogen, and, under unusual circumstances, by chlorine gas.

The habitability of a submarine from the standpoint of atmospheric conditions depends upon such factors as pressure, movement, temperature, humidity, and constituents of the air.

Discomfort, symptoms of heat exhaustion or heat stroke, and what is commonly called "crowd poisoning" result when:

(*a*) The temperature is so high that the body cannot eliminate its excess heat;

(*b*) The relative humidity is so high that perspiration cannot be evaporated from the surface of the body with the consequent cooling effect; and

(*c*) There is no movement of air to remove the hot moist blanket of air which accumulates around the body, and stimulates the heat regulating center in the medulla.

Air Temperature.

The air temperature in a submarine is often extremely high, especially in the tropics. Running submerged some cooling is obtained by conduction through the hull on account of its contact with the cooler sea water. The newer submarines are equipped with an air-conditioning plant. When the air-conditioning unit is functioning, it effectively lowers the temperature and humidity. Submarines on extended patrols in tropical waters have reported that air-conditioning makes a vital difference in the staying power of the crew.

Air Humidity.

The relative humidity of the air in a submarine can be determined by wet and dry bulb (psychrometer) readings. This often approaches the saturation point, particularly during an extended submerged run under battle conditions with the air-conditioning unit, and all fans and blowers secured. Moisture is given off from the skin and lungs at the rate of approximately 1 ounce per hour per man at rest. This amount is greatly increased by bodily activity. Moisture is also given off from the food in cooking and from the batteries by evaporation. High relative humidity with high temperature causes considerable discomfort to the crew. It causes the bulkheads to drip moisture, and makes all clothing mattresses, etc., continually damp, thus adding to the health hazards of the crew.

To find the relative humidity of the air whirl a sling psychrometer which contains wet- and dry-bulb thermometers rapidly for a few minutes. Note the wet- and dry-bulb readings, then subtract the wet-bulb reading from the dry-bulb reading, note the difference, and refer to the table accompanying the psychrometer. This table gives figures that represent the relative humidity when the dry-bulb temperature and the difference in degrees between the readings of the two thermometers are known.

Air Constituents.

The following gases are found in normal air approximately in the percentages shown:

	Per cent
Nitrogen	78
Oxygen	21
Argon	0.94
Carbon dioxide	0.03
Helium	trace
Krypton	trace
Neon	trace
Xenon	trace
Hydrogen	trace
Hydrogen peroxide	trace
Ammonia	trace
Ozone	trace

Normally the air within a submarine operating on the surface does not vary greatly from outside air, but during extended submergence the composition of the air may become so altered by vitiation and contamination as to be dangerous. The gases important in this connection are next discussed.

Hydrogen.

This is a colorless, odorless, physiologically harmless, but chemically active gas. An air mixture containing 4.1 per cent of hydrogen is inflammable and percentages higher than this may be explosive. Hydrogen in a submarine is produced by electrolysis within the storage batteries, particularly during charging. Each battery compartment contains a hydrogen detector for determining the percentage of hydrogen in the air system.

Carbon Monoxide.

This gas results from the incomplete combustion of any kind of fuel and is a constituent of the exhaust gases of engines. It may be found after fires or explosions in closed compartments where there is insufficient supply of oxygen to afford complete combustion. This gas, even if present in concentrations of only 1 part in 10,000, combines with the hemoglobin of the blood to form a stable compound, which will not carry oxygen to the tissues. Carbon monoxide is particularly dangerous because it is odorless, and those exposed to it are often unaware of any ill effects until they collapse.

If the presence of this gas is suspected in a compartment, no one should enter unless wearing the "lung" provided with a Hopcolite canister filter. Information regarding this procedure is contained in the Bureau of Ships pamphlet titled "Submarine-Respiration and Rescue Devices" which is available to all submarines.

Carbon Dioxide.

This gas is formed continuously in the body by oxidation of carbohydrates in the tissues. Increasing the oxygen tension has no beneficial effect unless the excess carbon dioxide is removed. The respiratory quotient, or R. Q., is given by the fraction: $\frac{CO_2 \text{ produced}}{O \text{ consumed}}$. Normally this ratio of volume of carbon dioxide produced to volume of oxygen consumed averages 0.82. The average normal oxygen consumption per man aboard submarines has been determined to be 0.9 cubic feet per hour, and the carbon dioxide produced per man may be cal-

culated as 0.9 x 0.82 or 0.74 cubic feet. Thus a submarine of about 26,000 cubic feet of air space, with a crew of 50 men, may safely operate submerged for about 20 hours without the release of oxygen or the use of carbon dioxide absorbent. This time is calculated from the formula, $x=\frac{0.04C}{N}$ in which x is the number of hours submerged, C the net air space in cubic feet, and N the number of men in the crew. Then $x=\frac{0.04 \times 26{,}000}{50}$ or 20. Further information on the habitability from this point of view may be found in chapter 27, section I, of the Bureau of Ships Manual.

There are individual variations in tolerance to carbon dioxide, but in general, tensions of 3 per cent cause only mild symptoms, between 3 per cent and 6 per cent, headache, discomfort, and deep breathing, between 6 and 9 per cent, extreme distress, panting ,and collapse. Tensions above 9 per cent are rapidly fatal. If flooding for escape is contemplated, it is of vital importance that as much carbon dioxide as possible be eliminated from the atmosphere. For, as in the case of oxygen, the physiologic effect of the carbon dioxide is in direct proportion to its partial pressure (which is a function of the percentage and the pressure in terms of atmosphere).

The removal of carbon dioxide is accomplished by the use of carbon dioxide absorbent, which is spread in mattress covers when necessary. The complete description of the method of testing for carbon dioxide and the use of the absorbent also is contained in the Bureau of Ships Manual.

Oxygen.

A colorless, odorless gas that constitutes 20.93 per cent of the atmosphere. It is physiologically necessary for life and should not be allowed to fall below 17 per cent. Inasmuch as carbon dioxide is produced as oxygen is consumed, there is usually ample warning of oxygen lack, simply by evidence of increased carbon dioxide. The classical symptoms of anoxemia are weakness, vertigo, cyanosis, nausea, and collapse. Oxygen deficiency usually gives no warning, however, and collapse may be the first symptom noted.

No test for oxygen tension is provided in submarines, but the approximate oxygen percentage of the air in any given compartment, as altered by respiration, can be found by multiplying the carbon dioxide content by 1.22 and subtracting this from 20.93, the percentage of oxygen in pure atmospheric air. A practical indication of the amount of oxygen in the air is obtained by striking a match. If the wooden part of the match will not burn, lack of oxygen is at or beyond the danger limit. Oxygen cylinders are provided in each compartment on board a submarine and oxygen is "bled" into the boat as necessary. When required, sufficient oxygen is released from the cylinder to cause a drop in the gauge pressure of the cylinder in pounds per man equal to 0.9×14.7 (the normal atmospheric pressure per square inch) or 13.23 divided by the net capacity of the cylinder in cubic feet. This is repeated every hour. Thus, if the volume of the cylinder is 1.53 cubic feet and the initial pressure is 1,800 pounds, for a submarine with a crew of 43 men, oxygen should be released until the cylinder pressure in pounds drops $\frac{13.23}{1.53} \times 43$ or 372 and the gauge of the cylinder reads 1,428 pounds. If new type oxygen reducer valves are installed, the low-pressure valve should be adjusted so that the hand on the metering gauge is set at the number of men for which the oxygen is supplied.

During the flooding of a compartment preparatory to a "lung" escape, the partial pressure of gases will increase, i. e., at a depth of 165 feet or 6 atmospheres absolute, the oxygen content by volume would still be about 20 per cent, but the partial pressure would be increased 6 times, thereby exerting the physiological effect on the body of 1⅕ atmospheres of pure oxygen. The prolonged breathing of this concentration may be dangerous, therefore the oxygen content before flooding should not be greater than 20 per cent.

Ozone.

This gas, present in minute amounts around all electrical machines in operation, is generated in appreciable amounts by ultraviolet lamps. Therefore, if ultraviolet bacteriological lamps are added to the present ventilating installation of any submarine, due precautions should be observed. Ozone is toxic even in a concentration of 0.04 part per million, causing respiratory irritation and pulmonary edema. The presence of ozone can usually be detected by its characteristic odor. Recent tests have shown that it does not constitute a hazard in submarines because it is very active chemically, oxidizing metals, rubber, paint, etc., and thus becoming rapidly decomposed.

Tobacco Smoke.

A real hazard in the submerged submarine is the presence of tobacco smoke. The effects are: Those due to the nicotine absorbed by the body, to odor, particularly of stale smoke, and to irritation of the eyes and respiratory tract. It should be pointed out that tolerance for tobacco varies greatly, and young individuals are more susceptible than adults. Some individuals appear to be allergic to tobacco smoke.

Although the acquisition of tolerance protects against unpleasant symptoms within limits, it is certain that the smoke in the rebreathed air of the enclosed space will exert its full harmful effect upon personnel not habituated to the usage of tobacco. It follows that under these conditions the smoking of tobacco should be forbidden.

Submarine experience indicates that although habitual smokers may be somewhat distressed for a day or two, they can adopt themselves without hardship to a routine that permits smoking only when ventilation is adequate.

Apart from its inherently toxic effect tobacco smoke, by virtue of its accelerative influence on pulse rate, acts as a complicating variable to confuse estimates of cardiovascular fitness and response to deleterious environment expressed in terms of pulse rate.

BACTERIOLOGY OF THE AIR

Owing to confined living quarters and the peculiar ventilating problems of submarines necessitating rebreathing of the air, contact and air-borne infections may become significant.

Bacterial counts of submarine air reveal the presence of bacteria in considerable numbers. *Staphylococcus albus* is the predominant organism, originating probably in large part from human skin and hair. Streptococci from the throat and respiratory tract are also found, as are gram-negative bacilli, molds, and other organisms in small numbers. These bacteria apparently are not present in greater numbers than in the living quarters of surface craft such as destroyers. Prolonged periods of submergence do not seem to cause an accumulation of bacteria in the air in greater numbers than are found while operating on the surface.

Dust counts are apt to be low but the same organisms have been recovered from sweepings as from cultures of air samples. Comparisons of dust and bacterial

counts suggest that most bacteria in the air are present on dust particles stirred up by air currents caused by human activity. The relative humidity of submarine air is usually high enough to produce dampness on the decks and uninsulated surfaces. This may have the effect of laying dust particles and thereby reducing bacterial counts. The presence of numerous oil droplets in the air of certain compartments may also assist in this process. Analysis of the water of condensation collected from the coils of the dehumidifier reveals a nearly sterile water, which would tend to exclude the washing-out effect of dehumidification as a possible mechanism in reducing the number of bacteria in submarine air.

The effect of battery gases on air-borne bacteria is as yet undecided, but there appears to be no lowering of bacterial counts during the time batteries are being charged. Records of extended war patrols reveal that outbreaks of colds and other respiratory infections are apt to occur early in a cruise, with relatively good health in the ensuing weeks. This indicates the prompt spread of the introduced infection and its subsidence after equilibrium is established with the infecting organism, since no new infecting agents are introduced. Otitis externa and trichophytosis, caused by fungi, may, however, persist because of high temperature and humidity. Control measures under consideration for the prevention of the spread of respiratory infections on submarines include ultra-violet irradiation of the air, the use of germicidal vapors or "aerosols" such as propylene glycol, and detention periods for the crew before embarking on patrols. This last measure might prove impractical, but throat cultures obtained a few days before sailing would prevent possible future trouble by providing for the elimination of carriers of group A streptococci, diphtheria bacilli, and epidemic types of meningococci.

DIET

On account of the unusual living conditions on a submarine, the limited food-storage space available, and the long duration of wartime patrols, careful selection and preparation of the food for submarine crews assumes special importance. Fresh fruit and vegetables in sufficient quantities to last longer than a few weeks cannot be carried; therefore, canned fruit, fruit juices, and vegetables, as well as various dehydrated products must be included in the supplies. Dehydrated foods are highly desirable because they conserve space and have recently been made very palatable. In all cases it is best to carry boned meat to reduce the weight and storage space required. The major part of this should be beef. A good supply of powdered milk should always be on hand.

In addition to the regular diet, all submarines are provided with multiple-vitamin capsules, each capsule containing one-half the daily requirement. The pharmacist's mate is directed to issue these vitamin capsules to the crew during patrols at the rate of two capsules per man per day, starting the tenth day at sea.

Associated with the problem of diet is the ever-present one of constipation among submarine crews. Improper eating habits, the small amount of roughage available in the diet, insufficiency of fresh fruits, movement of the ship, and the irregularity of meals and sleep all contribute to this difficulty. In addition, the toilet is difficult to operate. A new type that flushes into a central tank rather than overboard with each operation has been installed on some of the larger submarines. It is desirable that the intake of starchy foods, such as bread, potatoes, rice, corn bread, biscuits, and hominy grits, be reduced and some of the following be served and eaten at least once daily: Prunes, apricots, apples, figs, raisins, fruit salad, and vegetables.

NOISE

It has been demonstrated that long continued exposure to the noise of Diesel engines may lead to permanent loss of auditory acuity. In addition to such actual loss of hearing, the noise and confinement have a deleterious effect on the nervous system and general well-being of the man, increasing nervous tension and fatigue. Further quieting of submarine engines is desirable. Care should be taken to insure that all machinist's mates be supplied with some sort of ear protectors and that they be made to wear them. A shielding device which cuts out the high peaks of sound should be used by the radiomen in all receiving sets. Although the loss of hearing immediately experienced from a single trauma may not be great and may seem to be only temporary, repeated trauma has been shown to result in permanent loss of hearing.

PERSONNEL SELECTION

In view of the mechanical complexity of the submarine, the cramped living conditions which necessitate close personal contact among the crew, and the fact that each member of the crew must be able to handle more than one job, it becomes obvious that careful selection is necessary to make sure that men entering the submarine service are in good health and are temperamentally fitted for this special duty. The physical standards set forth in paragraph 1535 of the Manual of the Medical Department, U. S. Navy, are high and their purpose is to eliminate all those individuals with any chronic disease (upper respiratory infections, gastritis, venereal disease, etc.) or who are otherwise physically unfit for this duty. In addition to fundamentally good health, it is necessary that the men be qualified with respect to their level of intelligence and emotional stability. This is accomplished by administering mental tests for the determination of intelligence quotient and by conducting neuropsychiatric examinations. These tests have been found to furnish valuable data to supplement the purely physical picture. In cramped quarters, in overheated, damp air, away from natural sunlight, the close contact for long periods of times makes intolerable those mental and emotional defects which would otherwise cause no trouble. Supplemental examinations are employed to determine physical and mental ability to operate submarine devices, particularly soundgear.

THE MEDICAL DEPARTMENT REPRESENTATIVE

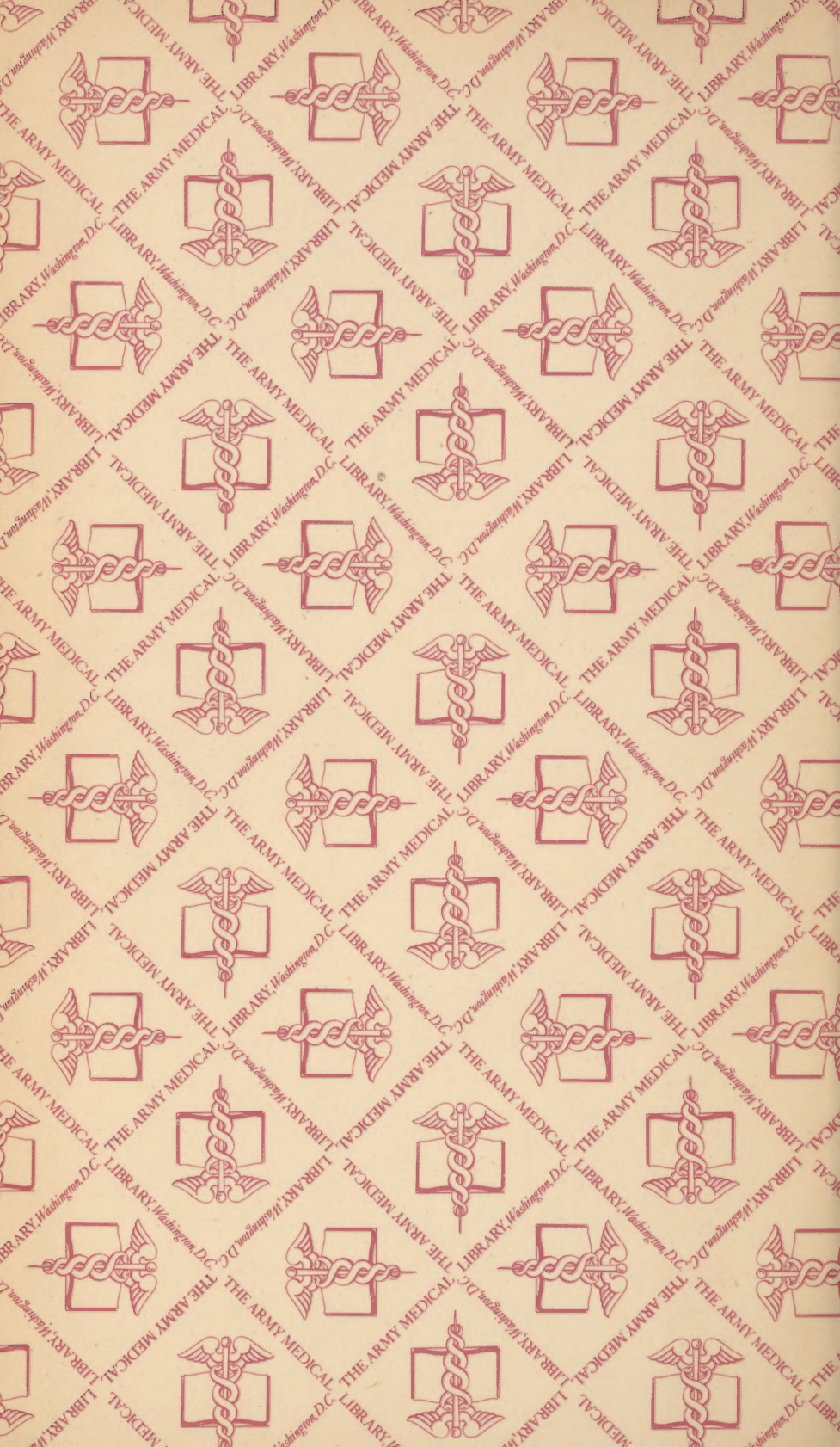
The maintenance of the health and well-being of submarine crews being a specialized problem, the medical-department representative charged with this responsibility should be an especially qualified man. The pharmacist's mate assigned to a submarine is a picked "independent-duty" man and his duties are manifold. Not only does he take care of the general medical-department activities; i. e., the care of the sick, the first aid and care of the injured, transfer of those beyond the scope of his care to shore or tender activities, but also he has numerous routine ship's company duties assigned to him. He issues the vitamins and stimulants (as for example, to the lookouts exposed to inclement weather for long periods), and supervises the daily treatment of all the crew and officers with the ultraviolet lamp carried in submarines.

All health records must be checked and kept up to date and he must see that all inoculations and vaccinations are given. He must familiarize himself with the crew, noting such things as personal habits of cleanliness, loss or gain of weight, the effects of heat or stress on individual men, the presence of skin

diseases, lice, etc. If he knows what a man looks like when healthy he will be better able to notice any changes due to sickness, and in many instances will notice such changes before the man becomes disabled and will take the necessary preventative steps. The pharmacist's mate must inspect the boat frequently for dirt and vermin, paying particular attention to galleys, heads, bed linen, etc. It need not necessarily be done in the form of formal inspections but informally as his duties take him to various parts of the ship. Instruction of the crew in venereal prophylaxis, first aid, and personal hygiene must be given. He must check all food coming aboard as to quality and all food served as to the cleanliness of its preparation, whether or not it is well cooked and served properly in well-balanced meals. A venereal inspection of the entire ship's company must be made at least once a week while in port. In all probability he will be the ship's librarian and general "odd-job man".

The question of "how far should I go in treating this case" will present itself time and again to the pharmacist's mate on submarine duty. It would be unwise to establish a rule or rules governing this, but it should never be forgotten that the primary duty is to prevent disease, to prevent injuries, and to preserve the life and limb of the person afflicted. The capable pharmacist's mate will, considering all things and knowing his own ability, decide what is best for his patient, always remembering that the life of his patient will often depend upon his decision.

INDEX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